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COMBINED SEPTIC TANKS, CONTACT BEDS, INTERMITTENT FILTERS AND GARBAGE CREMATORY, MARION, O.

By R. Winthrop Pratt.*

The city of Marion, O., having a population of about 15,000 and an area of seven square miles, is located in the central part of the State, upon the drainage area of the Scioto River. The city lies in the midst of a particularly rich farming district. It has exceptionally good railroad facilities, due to the concentration of five railroads at this point. It is fast becoming a large manufacturing center, and it already contains the large works of several important industries. It is quite probable that there will continue to be a healthy and rapid growth of the city.

Marion is supplied with water furnished by a private company. The works were built in 1890. The supply was first obtained from a reservoir situated in the gravel drift, but later this supply was supplemented by ten 8-in. wells passing through the drift into the underlying rock to depths of 100 to 200 ft. There are 27 miles of water mains, through which water is supplied to about half the population. The average daily consumption is about 800,000 gallons, nearly all of which is used for domestic purposes. The water consumption, however, by actual measurement, is more than twice as large as the flow of sewage.

The topography of Marion and the adjacent country is rather flat, although good drainage and sewerage are obtainable. There is no natural stream in the immediate vicinity of the city. Artificial ditches convey surface water to the Little Scioto River, some three miles west of town, and the domestic sewage flowed to the same river through an 18-in. outfall sewer until the new sewage works were installed.

Marion has some 16 miles of domestic sewers, which are built in accordance with a plan of sewerage for the entire city, prepared some ten years ago. These sewers are used by approximately 6,000 people. There are also several miles of storm sewers. The latter receive in some cases household drainage, but this is being eliminated. The average dry weather flow of domestic sewage, based upon gagings made at the main outlet, is about 350,000 gallons per day, but this flow is increased considerably at times of rain, owing to a large number of roof and cellar drain connections, and also possibly to leakage into the main sewer. The increased flow continues only for short periods. Practically no surface water from the streets is admitted to the domestic sewers, and there are no manufacturing wastes to affect the character of the sewage. The sewage from the main outfall sewer formerly created extremely foul conditions in the Little Scioto River near the outlet, three miles southwest of town. Furthermore, the same river, some 40 miles down-stream, is used as a public water supply for the city of Columbus.

Marion has no complete system of garbage and refuse collection. The city owns a six-acre tract of land, east of the corporate limits, upon which garbage, collected by independent scavengers, is dumped. An old quarry is also used for the reception of garbage and street sweepings. A proper system for the collection and disposal of the city's garbage is, therefore, decidedly necessary. It is estimated, from the amount now collected by the different scavengers, that with a thorough system of collection the daily quantity would be 12 to 15 tons. Ashes and street sweepings are at present used for filling.

In September, 1904, the State Board of Health approved general plans for a sewage disposal plant combined with a refuse incinerator or crematory. The work of construction was started the following month and finished in October, 1905, after considerable delay due to bad weather, difficult excavation and labor troubles. The plant is located about one mile west of the edge of the built-up portion of the city. This location was chosen after thorough investigation, and is very satisfactory. The haul for garbage is quite reasonable, and yet the plant is well beyond any land which will probably be used for residential purposes for a considerable number of years. The site is also so located near the course of the main intercepting sewer that it was only necessary to tap this sewer and lay about 1,000 ft. of additional 18-in. pipe in order to convey the sewage to the plant at a sufficient elevation to permit of its passing through the various processes by gravity.

GENERAL VIEW OF COMBINED SEWAGE AND GARBAGE AND REFUSE DISPOSAL PLANT, MARION, O.

SEWAGE DISPOSAL PLANT.

The dry weather flow of the Little Scioto River near Marion, being only 1 or 2 cu. ft. per sec., is entirely inadequate to inoffensively dilute any considerable quantity of unpurified or even partially purified sewage. It was therefore necessary to design a sewage disposal works capable of producing an effluent which would at all times be non-putrescible. The use of the Scioto River for a water supply by the city of Columbus also made it very desirable to obtain as high a degree of purification as practicable, in order to reduce to a minimum the danger to which the people of Columbus were subjected on account of the discharge of sewage into the river at Marion. At the time the plans were made it was by no means decided that a filtration plant would be built to purify the Columbus water supply. Since then such a plant has been put under construction. Nevertheless, it is very desirable to have the raw water arrive at Columbus with as little pollution as possible.

The sewage purification plans adopted and carried out at Marion include screens and a grit chamber, septic tanks, contact beds, and, finally, intermittent filters composed of sand overlying fine broken stone or "screenings." The sewage works have a nominal capacity of 600,000 gallons per day.

Our first engraving is a general view of the combined sewage and garbage disposal plant. Fig. 1 shows the details of the sewage works; Fig. 2 the underdrainage system of one of the contact beds. Figs. 3 and 4 are views, and Fig. 5 shows details of the crematory.

The sewage, on arriving at the plant (Fig. 1) through the newly laid portion of the main sewer, passes through a set of two screens which have a mesh of 1 in. These screens are easily removed for cleaning. The material scraped therefrom is deposited in the refuse incinerator through one of the dump holes, which is about 15 ft. distant from the screen chamber. After being screened

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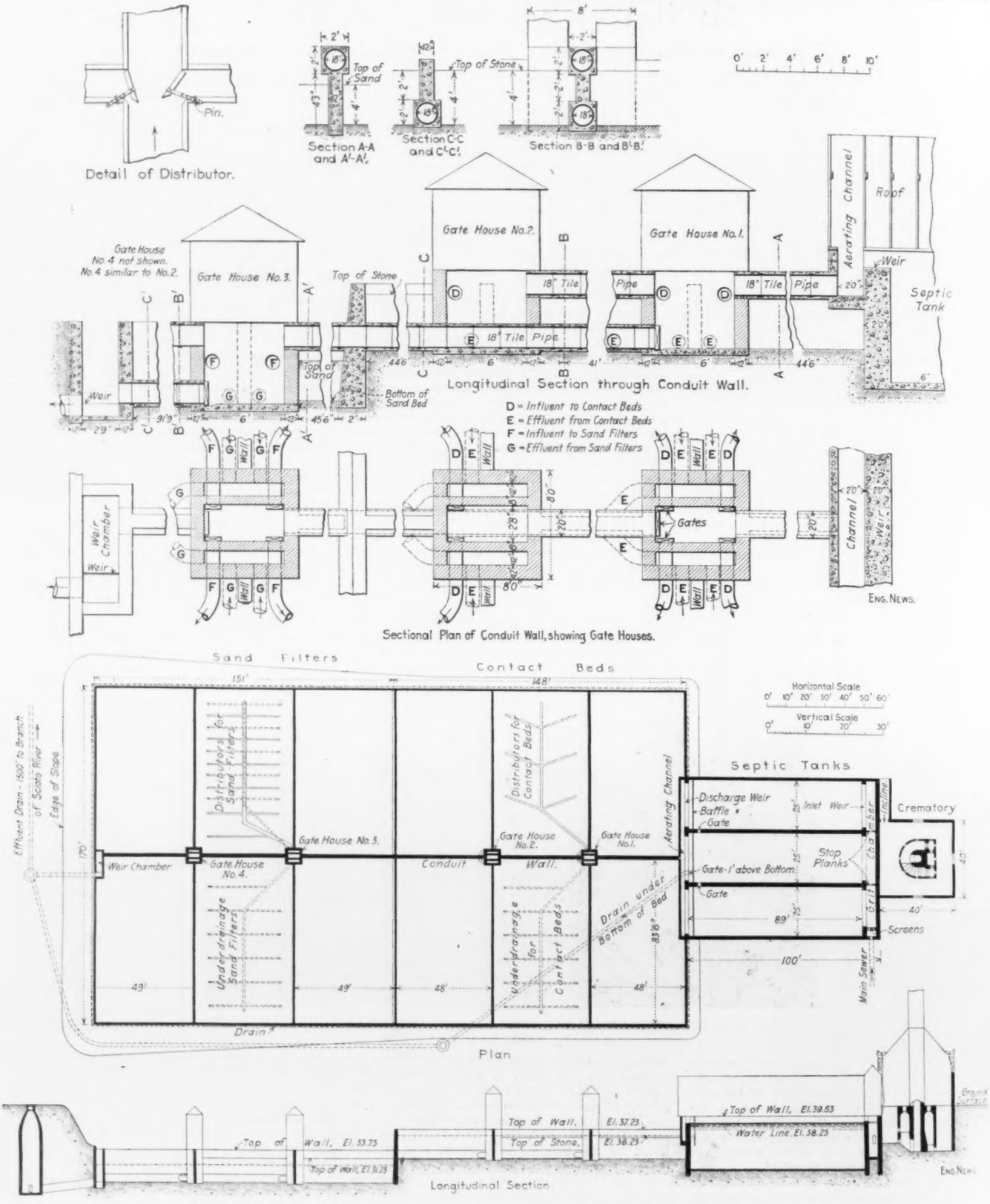


FIG. 1. PLAN, LONGITUDINAL SECTION AND DETAILS OF SEWAGE AND GARBAGE DISPOSAL PLANT, MARION, O.

the sewage passes into the narrow grit chamber, which extends across the upper ends of the three parallel septic tanks. The sludge deposited in the grit chamber is to be dumped directly on to the evaporating floor of the crematory and there destroyed.

From this chamber the sewage may be directed by means of stop-planks into one, two or all three of the septic tanks. These tanks are each 25 ft. × 89 feet. inside, with an average depth of 8 ft. below the flow line, and each holds about 130,000 gallons. The concrete walls of the tanks are 2 ft. thick. Baffle boards, extending 5 ft. below the surface, are placed within 2 ft. of the lower end of the tanks. Passing under these baffle boards, the sewage overflows in a thin stream over a weir, formed by the end walls of the tanks, and extending across their entire width, into a collecting and aerating channel, and thence through a conduit to the contact beds and filters. The septic tanks, grit chamber and aerating channel are covered with a substantial wooden roof. A box flue leads from the inside of this roof into the crematory stack. In this way a powerful draft is created and all offensive gases carried away or destroyed. By this ventilating system it is also possible, by keeping the

gate-house doors closed, to obtain more or less of a draft downward through the contact beds. This will probably be an advantage in oxidizing the organic matter accumulating in these beds.

All three septic tanks are connected at the bottom by means of gates, which are kept closed under normal conditions. This allows one tank to be emptied for cleaning while the others remain in use. Leading out of the middle tank, at a point a little more than a foot above its bottom, is an outlet controlled by a gate, through which the upper 6 or 7 ft. of the contents of the tank can be drawn out and passed directly to the river. The draining out by gravity of material below the level of this gate is impossible. By this arrangement it is expected that, in case the septic tanks require cleaning, the liquid will be drawn down to a point within a foot or so of the bottom; but that the most offensive matter must remain in the tanks and be pumped into the crematory. Such a plan is satisfactory if the time for cleaning is chosen when there is high water in the river, as the river at such times, in spite of the low dry weather flow, contains a volume of water sufficient to dilute in an entirely satisfactory manner an amount of sewage and sludge far greater than can be stored in the tanks.

From the aerating or collecting channel the septic tank effluent passes, under the usual procedure, through an 18-in. vitrified pipe laid in the concrete longitudinal dividing or "conduit" wall to the first gate house, from which it may be diverted on to any or all of four contact beds; or the sewage can pass through the first gate house to the second, where it may be diverted on to one or both of two contact beds. The tank effluent may also be directed, if desired, to the sand filters or to the final effluent drain without being filtered.

The contact beds are six in number, each 48 × 83½ ft., inside dimensions, and contain 4 ft. of broken stone. The lower foot of this stone is composed of pieces of an average diameter of about 2 ins., while the upper 3 ft. consists of pieces of ½ to 1½ ins. in diameter. The bottoms of these beds are formed of clay puddle, rolled to grade. Upon the puddle rests the underdrainage system, consisting of one main drain 12 ins. in diameter and extending longitudinally through each bed, with 11 lateral lines of horse-shoe tile, 6 ins. wide, entering it (see Fig. 2). The sewage is distributed over the surface of the stone by means of wooden troughs. The walls which separate the contact beds are of concrete, 1 ft. thick, and extend 1 ft. above the surface of the filtering material. Considering the broken stone to be one-third voids, the contact beds, when the plant has reached its nominal capacity of 600,000 gallons per day, will operate at the rate of 2½ contacts per day.

Under normal operation the contact bed effluent, purified nearly to or perhaps just beyond the non-putrescible stage, flows through the main underdrain back into one of the gate houses, and thence through a conduit to the "sand filters." These filters are six in number and are practically of the same area and shape as the contact beds. They are placed at an elevation some 4 or 5 ft. below the latter, so that they receive the contact bed effluent by gravity. The underdrainage system of these beds is about the same as that of the contact beds.

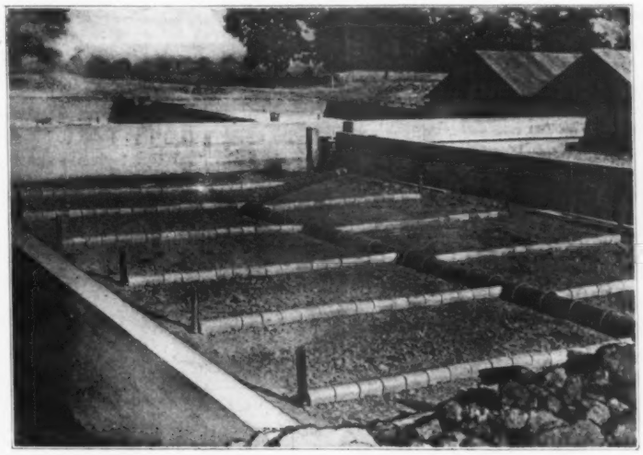


FIG. 2. UNDERDRAINAGE SYSTEM FOR SEWAGE CONTACT BED, MARION, O.

The filtering material in the "sand filters" consists, first, of 6 or 8 ins. of broken stone, consisting of pieces of ½ to 1½ ins. in diameter. This layer covers the underdrains. Next, above, is a 2-ft. layer of fine limestone screenings, which are comparable to fine gravel. Mechanical analyses of these screenings show the effective size to be about 0.8 mm. and the uniformity co-efficient to be 6.0. Above the screenings is placed a 6 or 8-in. layer of Lake Erie sand of a superior quality. The effective size of this sand is .35 mm. and the uniformity coefficient is 3.5. As in the case of the contact beds, the sand filters are closed by concrete walls 1 ft. wide. With the nominal capacity of the plant, these filters will be operated at a rate of about 1,000,000 gallons per acre per day.

The reason for using the stone screenings instead of making the filters entirely of sand was the impossibility of getting suitable sand in the vicinity or of hauling it in at a reasonable cost. As experimental investigations, both in this country and abroad, have shown that by far the greatest part of the purification which takes place in sand filters occurs within the top 4 to 6 ins., it is thought that the arrangement adopted will produce practically as good results as those which would be obtained with the filters made entirely of sand. In any case, since the sand filters are used only to finish the process, and must be operated at high rates, the material would have to be fairly coarse; and the screenings used are not much coarser than a very coarse sand or fine gravel. These screenings were hauled 40 miles by rail and one mile by road, but cost less than suitable sand.

These intermittent filters at Marion are very similar in principle to the "controlled filters" of Baldwin Latham, discussed in the editorial columns of the Engineering News, Dec. 21, 1905. The Latham filters contain a different, and it would seem a poorer, quality of material; but the size of material and the rate of filtration are quite similar to those at Marion. With the latter, however, the applied sewage, having first been treated in septic tanks and contact beds, instead of being simply settled or lime-treated, is probably capable of being more highly purified in its passage through the filter.

The gate houses on both the contact beds and sand filters are brick structures, 8 × 8 ft. in plan, and contain three chambers each, the center chamber being for the influent to and the two outside or smaller chambers for the effluent from the group of filters or contact beds connected with each house.

The sewage is spread over the sand surface by means of wooden troughs, the distribution being more thorough than is necessary with the contact beds. These troughs are movable and can be adjusted to obtain the best distribution. (At the time the photograph, reproduced on the first page of this article, was taken the troughs were not arranged as intended.)

The final effluent from the plant, after passing out of one of the sand filter gate houses, flows into the weir chamber over a measuring weir, and then into the main effluent drain. This drain is 18 ins. in diameter and extends to Rock Swale Ditch, 1,500 ft. west of the plant. This ditch is a branch of the Little Scioto River, and enters the latter stream at a point about two miles south of the effluent outlet. At the time of an inspection by the writer, made after the plant had been in operation a short time, the final effluent was clear, colorless and odorless.

The plant is so arranged that the sewage can-

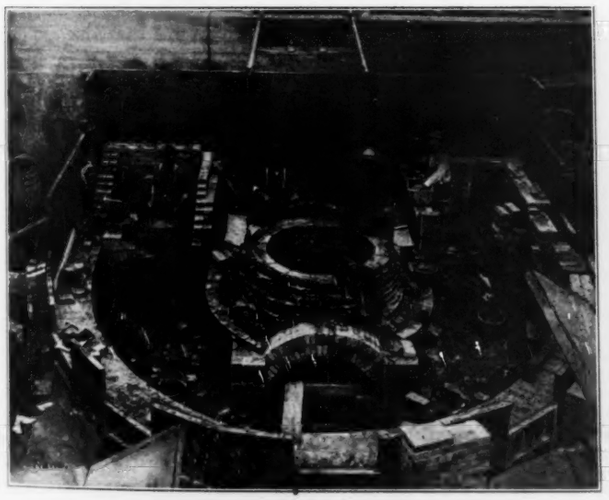


FIG. 3. WELL STARTED.

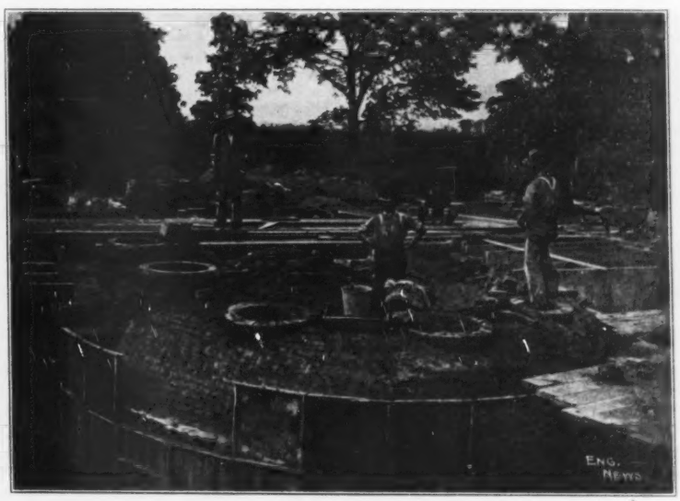


FIG. 4. PRACTICALLY COMPLETED.

FIGS. 3 AND 4. THE BRICKWORK AND CAST-IRON JACKET OF THE MARION GARBAGE CREMATORY UNDER CONSTRUCTION.

not be by-passed around the entire works, though the septic tank effluent, previously subjected to screening and a brief period of settling in the grit chamber, may, in case of emergency, be passed directly to the river. Reasonable provision is thus made for preventing gross pollution of the river under any circumstances. The practice of disposing of the sludge by cremation affords a very excellent method of preventing a possible nuisance around the plant, and the system of ventilating the tanks into the stack is a valuable additional safeguard against offensive odors.

The bottom of the contact beds is 9 or 10 ft. below the natural ground level; while the bottom of the sand filters is some 15 ft. below. On account of the clay soil the necessary excavation was very expensive. Especially was this true of the sand filters, which are placed in an extremely tough blue clay, containing many small boulders and stones. The process of getting this material out was very slow, as it could not be blasted, but could only be scraped, four horses to a scraper, in small quantities at a time. Frequently the loaded scraper would strike a boulder and lose nearly all of its contents. The bad weather which occurred while this excavation was under way also added to the difficulty and expense. It is estimated that some of the excavation for the sand beds cost as much as $3 or $4 per cu. yd.

Around the edge of the area occupied by the contact beds and filters, at the top of the side walls, is a drain which is designed to prevent clayey material from being washed down the slopes surrounding this area on to the filtering material. It is expected that these slopes will be covered with grass during the summer of 1906.

As the operation of the crematory requires attendance both night and day, it was decided in designing the sewage works that better efficiency could be obtained by omitting automatic devices for controlling the operation of the beds. The extra labor of opening and shutting the gates would, under these conditions, mean no increased expense to the city. The gate chambers are so designed that, if desired, apparatus may be installed which would cause a bell to ring in the office of the crematory when it is time for the attendant to change the gates. In any case, the attendant will soon learn, with a given flow of sewage, the time it takes to fill a contact bed. The gates controlling the flow on to the sand beds require comparatively little attention, and may be changed at a stated time each day.

GARBAGE AND REFUSE CREMATORY.

The crematory or refuse incinerator was built especially to suit the conditions at Marion, and contains several new features in its design. It is placed at the upper end of the septic tanks, the northerly wall of the grit chamber forming one foundation or basement wall for the crematory building (see Fig. 1).

The furnace or crematory proper (Figs. 3 to 5), located in the basement of the building, is a brick structure, entirely enclosed by a shell of cast-iron plates bolted together. A fire-brick lining, 4 to 12 ins. thick, is placed wherever the walls are subjected to great heat. The common brick, being much stronger and cheaper, were used wherever possible consistent with safety. The grate bars and also the plates forming the evaporating floor are of cast iron.

The southerly portion of the furnace is in plan a semi-circle, while the northern portion is rectangular. The outside dimensions of the furnace are 20 × 20 ft. In the center is a circular brick stack, 4 ft. inside diameter. This stack changes at a point 25 ft. above its base to a section 4 ft. square inside and 8 ft. square outside. The total height of the stack above its base is 101 ft., and the section at the top is 4 ft. square inside and 5½ ft. square outside. The 4-in. fire-brick lining extends from the bottom to a height of about 50 ft.

In the northerly end of the furnace are three combustion chambers. The middle and largest of these three chambers is 6½ × 5 ft. × 8 ft. high, and is designed to incinerate horses or other large animals, and also coarse rubbish, boxes, etc. The two end combustion chambers, called garbage cells, are each 3 × 4 ft. and 8 ft. high.

The solid cast-iron grate bars in the three combustion chambers are stationary, and are cleaned by raking the ash through them into the ash-pit beneath. The evaporating floor, which covers the remaining (circular) area inside the furnace, is composed of cast-iron plates, and is placed at an elevation of about 2½ ft. above the "dust arrester," or bottom of the furnace. Every fourth or fifth plate can be rotated, so that the material on the evaporating floor is easily transferred to the dust arrester beneath, and from there the incombustible matter is removed or stoked into the ash-pit. The evaporating floor is to be used in general to receive garbage, sewage-sludge and light rubbish.

The furnace, it will be seen, contains one very large cell and three smaller cells. The smaller ones are the combustion chambers, while the large one receives heat from the combustion chambers and is called the evaporating chamber, the bottom being formed by the evaporating floor. All the cells are top-fed, the large one having several openings.

The fuel used at Marion is natural gas, although the combustion chambers will permit the use of coal or wood. The natural gas is a very convenient, clean and comparatively cheap fuel. Four burners, designed especially for the furnace, make a powerful flame, some 3 ft. long, and one which can be easily regulated. The flame or intense heat originating in one or two of the combustion chambers passes over the evaporating floor and around the stack. From here the products of combustion are carried downward through a damper into the side combustion chamber, and after being subjected to the flame drop into the space beneath the evaporating floor, or dust arrester, and then up the stack. The heat can be short-circuited, as it were, if only a small amount of refuse is to be burned, by opening one of the revolving plates and causing the heat to pass over only a portion of the evaporating floor and thence downward into the dust arrester and up through the stack.

In operating the plant the plates forming the evaporating floor are not allowed to become entirely uncovered, but a certain amount of ash is left upon them for protection against the intense heat. The incinerator contains a total grate area of 43½ sq. ft., of which 19½ sq. ft. are in the middle combustion chamber, or animal cell. The evaporating floor contains an area of 170 sq. ft. These areas, compared to other works, seem to be very liberal for the rated capacity of the furnace. By the arrangement described the odorous gases from the drying garbage are thrown downward into one of the two side combustion chambers and pass through the flame before entering the dust arrester on their way to the stack. By the manipulation of dampers and gas burners the temperature in the furnace can be regulated as desired.

The foundation for both furnace and stack is

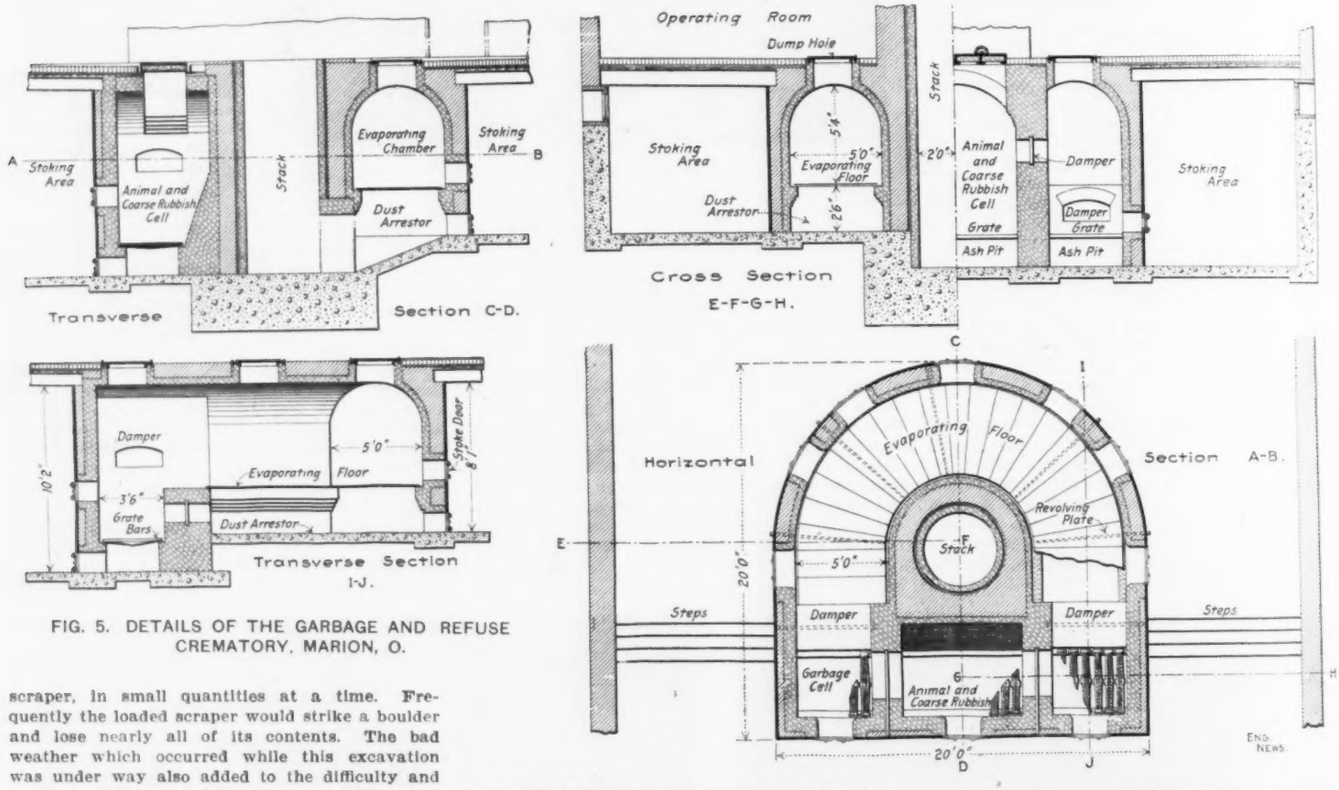


FIG. 5. DETAILS OF THE GARBAGE AND REFUSE CREMATORY, MARION, O.

of concrete. This is 3 ft. thick directly beneath the stack and 6 ins. to 1 ft. thick under the remainder of the furnace. The natural soil beneath the crematory, as well as that beneath the sewage works, is a tough clay. The bottom of the entire crematory, including the stoking area, is below the ground water level, and was constructed with considerable difficulty on this account. The concrete in this bottom was laid in sections, the water being pumped continuously from a sump. In placing the last section plaster of paris was used with good results in keeping out the ground water. The finished work is practically water-tight.

The crematory building is a neat structure, 40 x 40 ft. in plan, outside dimensions. The walls above the surface of the ground are of brick, while below the ground they are of concrete. The southerly concrete wall, which separates the grit chamber and septic tanks from the building, is 2 ft. thick, while the remaining concrete walls are 16 ins. thick.

The space in the basement between the concrete walls and the furnace is called the stoking area. This area is reached from the outside by means of an inclined plane, designed to allow the easy handling of fuel, in case other fuel than the natural gas is used, and also to allow any incombustible matter, such as tin cans, to be taken from the ash-pit or dust arrester and easily removed. Provision has been made for disposing of such matter by dumping it upon land adjacent to the plant.

The main floor of the building is on the level of the ground, and is called the operating or dumping floor. Wagons drive into the building on this floor and dump the garbage directly into the furnace through any of the eight openings. Seven of these opening are 2 ft. in diamter, while the eighth is 2¼ × 5½ ft. All of the openings are provided with iron rolling or sliding trap doors. The large opening is directly over the largest cell or combustion chamber, and through it horses may be dropped without cutting them into pieces.

The operating floor is constructed of paving brick, thoroughly grouted, resting upon a plank flooring. The floor is graded so that it may be easily cleaned, the scraping and washings being flushed into the dump holes. To facilitate this, water pumped by a windmill from a nearby well is stored in a tank located in the attic above the operating room.

The rated capacity of the crematory is 30 tons of mixed municipal refuse, in 24 hours, including garbage, night soil and dead animals. This capacity will allow for an increase in the present estimated daily yield of refuse from the city of about 100%.

No extensive tests have yet been made upon the crematory with reference to its efficiency for incinerating garbage, as the system of garbage collection, previously mentioned, at Marion is very incomplete; and a new system has not yet been inaugurated by the city officials. A severe test of the ability of the crematory to incinerate dead animals has been made, however. A fire in a livery stable in Marion, just at the time that the crematory was completed, made it possible to obtain the carcasses of eight dead horses. These were placed in the combustion chambers of the crematory, four horses being put, whole, in the large middle cell, while the remaining four were each cut into thirds and two deposited in each of the side combustion chambers. The gas was then lighted, the furnace being cold. One hour after starting nearly all of the material was consumed. The underneath portions, though small in total amount, were protected to a considerable degree by the ashes from the upper portions, and hence required a considerably longer time for complete incineration. Five hours after starting, however, the carcasses were completely reduced to ashes. The quantity of gas consumed in this test was about 30,000 cu. ft., the price being 15 cts. per thousand.

This shows what the furnace could do in an emergency, rather than what it will be called upon to do ordinarily; for in the usual course of operation it would rarely happen that such a large quantity of dead animals would have to be disposed of at one time.

The services of two men, one at day and one at night, are necessary to operate the crematory; and these men will also take care of the sewage plant. Night soil will be handled only at night, and provision must be made for disposing of it without delay after it reaches the plant.

It is interesting to note that, with the exception of the fire-brick, all materials and labor necessary for the construction of the crematory were obtained at Marion. The cast-iron plates and other ironwork were made at the local foundry, and the common brick were made in the near vicinity and laid by local masons.

COST OF THE COMBINED PLANT.

The total actual cost, not including engineering, of the combined sewage disposal works and the crematory was $60,500. This may be divided about as follows: Land, $2,500; crematory, $15,000; septic tanks, $10,000; contact beds, $13,000; sand filters, $20,000.

As mentioned above, the comparatively high cost of the work was due to the unexpected difficult excavation; to an extremely rainy season, which made some of the roads over which material had to be hauled almost impassable, and which delayed the excavation and masonry work; to the high price of filtering material; and to the difficulty in obtaining reliable laborers. This last difficulty was caused largely by the fact that the local laborers and team owners would not work during the planting and harvesting seasons, as their services were needed on the farms.

The combined plant was designed by and built under the supervision of Mr. George H. Pierson, C. E., of New York City, and the contractor was the Clinton Foundry & Machine Co., also of Nazareth, Pa. The garbage furnace was built under a license from Mr. Robert L. Walker, the patentee.

THE PREVENTION OF DUST ON ROADS AND RAILWAY TRACKS BY SPRINKLING WITH "WESTRUMITE."

One of the objectionable features of macadam paving is the dust formed by wear of the surface. The dust is a nuisance to persons riding upon or living near the roads, particularly where there is much automobile traffic. Various methods have been adopted to lay the dust and to consolidate the road material so as to resist abrasion and form a solid mass, and much impetus has been given to the attempts in this direction by the rapid growth of automobile traffic. The sprinkling of tar and oil upon the roads has been extensively tried, both in this country and abroad, and with considerable success in many cases. Experiments have also been made with numerous patented solutions. The sprinkling of completed roads is very efficacious in laying dust temporarily, but for more permanent and economical results it seems necessary to incorporate the material as a binding medium with the stone of the road surface, as noted in our issue of Feb. 8.

A material known as Westrumite, which has been extensively used abroad for the prevention of dust, is now being introduced in this country, and has been tried experimentally on Staten Island and in Chicago. It is a petroleum product, treated by a special process to make it mix with water, the material being applied in a solution of varying strength, according to the purpose for which it is to be used. No mixing apparatus is required, the liquid material being poured into the partly filled tank or sprinkling cart, which is then filled. The special advantage and economy lies in the fact that while with the use of water alone a street may require to be sprinkled several times a day in summer (and becomes dusty again very soon after each sprinkling), with the use of the Westrumite solution one sprinkling may suffice for several days. It has a slight odor when first applied, and it gives to the surface of the road a dark color, which is much more pleasant to the eye than the glaring white of a limestone road. It prevents water from soaking into the road, and, to some extent, acts as a binding medium, thus reducing wear; but its full value as a binder can best be obtained by mixing a 50% solution with the stone when surfacing the road. For sprinkling, a solution of 5% to 10% may be used for the first application and a 3% to 5% solution afterwards. The strength of the solution will, of course, depend largely upon the character of the road and the traffic.

The destructive effect of oil upon rubber tires has led automobile owners to object to the use of oil upon the roads, but it is claimed that Westrumite has no such effect. The material may be used not only for macadam roads, but also on sand, gravel and dirt roads, and for sprinkling railway ballast. It can be added to the sand used as the cushion bed and joint filling of brick or stone block paving, and may be used in sprinkling any kind of pavement to reduce the dust.

In Europe this material has already been used to a considerable extent, notably on stretches of road to be used for parades or automobile races. City and highway authorities and railway companies have used it, and a number of officials have approved of its use, especially in Germany, where the roads and streets are under engineering supervision. At Nijmegen, where the public square (Kaiser Karl Platz) was watered ten times daily by two men with hose from the hydrants, it was estimated that equally good results would be obtained with one sprinkling of a 5% Westrumite solution every two or three weeks. Analyses of dust at this place showed the following results:

	Dust from Ordinary street. %	Freshly treated street. %	Street 3 weeks after treatment. %
Moisture	0.491	0.988	0.934
Watery extract	0.208	0.484	0.429
Alcoholic extract	0.067	1.601	0.977
Ethereal extract	0.092	1.908	1.015
Specific weight	2.432	2.305	2.290

The most extensive experiment with Westrumite in this country has been made in Chicago on the south drive of the Midway Plaisance, and we are indebted to Mr. J. F. Foster, General Superintendent of the South Park Commission, for a copy of his report on this experiment. The area sprinkled was about 31,240 sq. yds.; the paving was of limestone macadam, the surface being of stones not exceeding 1 in. in size, packed with limestone screenings. The drive was very clean when first sprinkled, with very little fine material on the surface; the cross drives had not more than ⅛-in. of fine material. The traffic consists of carriages, automobiles and bicycles; it averages from 100 vehicles per day on unfavorable days to 800 or 900 on Sundays and pleasant days. The sprinkling was done with the ordinary park sprinkling wagons. After two applications of a 10% solution on Aug. 21 and 22, no further application was made for six days, and there was no dust or mud on the drive, but the cross drives had to be sprinkled with water on the fifth day. The quantity applied was 0.31 and 0.175 gallons per sq. yd. At intervals of six to twenty days up to Nov. 11 the sprinkling was renewed, a 5% solution being used, and the quantity being from 0.216 to 0.335 gallons per sq. yd. Omitting the first two applications, there were eight sprinklings. At each application the wagon passed twice over the surface, the quantities given representing the total amounts applied. We give the principal conclusions of Mr. Foster's report, as follows:

First.—After a macadam driveway, such as the south drive of the Midway Plaisance, has been well covered with Westrumite by three such applications as named above, an application of one sprinkling of 5% Westrumite, 0.17 gallon of the solution per sq. yd., at average intervals of eight days during the summer, will constantly prevent dust.

Second.—Where there is no restriction as to the character of the traffic on a driveway, an application of 5% Westrumite, 0.335 gallon of the solution per sq. yd., will have to be made at average intervals of four days during the summer to prevent dust.

Third.—The preventing of dust on a driveway like the south drive of the Midway with 5% Westrumite solution, 0.17 gallon per sq. yd., applied at average intervals of eight days, will cost 6.4 mills per sq. yd. per month. To sprinkle with water alone in the manner such sprinkling is done in the South Parks, costs 4.15 mills per sq. yd. per month. To sprinkle a mile of 40-ft. driveway with Westrumite, as last above described, will cost $150.10 per month; with water alone, $97.39 per month. In neither case is the cost of water considered, as there is no charge for water to the South Park Commissioners.

Fourth.—The benefits to be derived from the use of Westrumite are: (A) That there will be no dust on the driveway at any time during the 24 hours. Whereas, with the best possible sprinkling with water alone (unless it should be done in the night time as well as during the day) there will frequently be dust in the evening, morning, during feed hour and at night.—(B) My ob-

servation so far leads me to think that Westrumite sprinkling, if it is well done up to the middle of November, will prevent dust on macadam roads during the winter; except, perhaps, on driveways that are used as greatly as the driveway of Michigan Ave. north of 33d St. On the other hand, with water sprinkling, it is very difficult to prevent heavy dust storms in winter, even if salt is used in the water when the temperature is below freezing, as is done on the South Park driveways.—(C) A much better sanitary condition is secured by the use of Westrumite, owing to the absence of dust at all times.—(D) The surface of the driveway is much darkened by the use of Westrumite, which is desirable.

Fifth.—The objections to the use of Westrumite are as follows: (A) The cost, considering saving in gutter cleaning and winter sprinkling is 45% greater than the cost of sprinkling with water without Westrumite. If, however, the cost per hour of preventing dust is considered, then sprinkling with Westrumite would be cheaper than sprinkling without.—(B) A disagreeable odor for two days after each application, which is quite objectionable.—(C) It makes the driveway somewhat slippery; not as slippery as sheet asphalt or wooden blocks, but sufficient to prevent some people from driving upon it if there is a water-sprinkled macadam road that can be used instead.—(D) There are some evidences of disintegration of the surface of the macadam on the driveways where Westrumite has been used, caused probably by the want of moisture. To what extent this may go can only be told after a more extended use of Westrumite.—(E) When first applied, it makes the driveway somewhat objectionable to pedestrians, though not more so than is caused by heavy water sprinkling.

Automobiles do not seem to affect the Westrumited driveways to any greater extent than they do a water-sprinkled driveway, if as much. I have been unable to determine whether or not Westrumite on a driveway is harmful for rubber tires, but the inference is that it must be somewhat so, as oil tends to disintegrate rubber. The use of Westrumite on driveways, so far as I have observed, works no injury to the grass, shrubbery or trees in the neighborhood.

As to the desirability of using Westrumite in driveway sprinkling: Without doubt it would be a great comfort to all users of the park driveways, [illegible] as to those who reside or do business upon the boulevards, to have the driveways free from dust at all times, day or night, winter or summer, which condition [illegible] be obtained with Westrumite. I believe that, aside from the cost, the other objections to the use of Westrumite are not of sufficient weight to overbalance the benefits named.

In regard to the objection as to cost, stated in Mr. Foster's report, it is to be noted that at present the material has to be imported. A plant is now being erected near Chicago, however, so that by next spring the Westrumite may be obtainable at a very much lower price. This material is the invention of Mr. Leonard S. Von Westrum, of Germany, and is being introduced in this country by the Westrumite Co., 1117 Monadnock Block, Chicago.

THE REPORT OF THE BOARD OF CONSULTING ENGINEERS FOR THE PANAMA CANAL.

The Report of the Board of Consulting Engineers for the Panama Canal was made public on Feb. 19.

As already outlined in the newspapers, the majority report recommends a sea-level canal, and is signed by General Davis and Messrs. Parsons and Burr, and by the five foreign members of the Board, while the minority report, favoring a lock canal, is signed by Messrs. Alfred Noble, Henry L. Abbot, Frederick P. Stearns, Joseph Ripley and Isham Randolph.

The complete text of the majority and minority

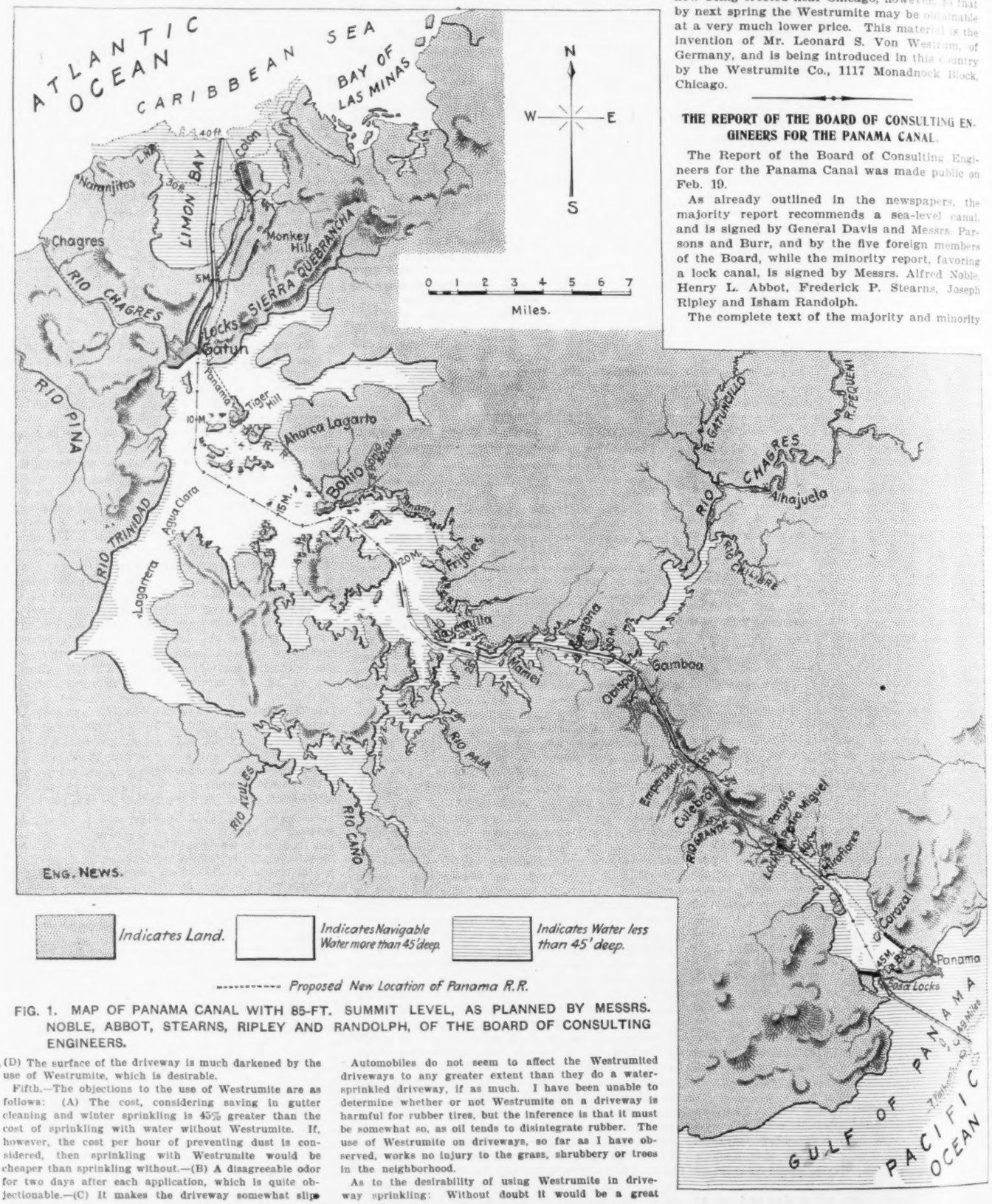


FIG. 1. MAP OF PANAMA CANAL WITH 85-FT. SUMMIT LEVEL, AS PLANNED BY MESSRS. NOBLE, ABBOT, STEARNS, RIPLEY AND RANDOLPH, OF THE BOARD OF CONSULTING ENGINEERS.

reports makes a quarto volume of 100 pages, which is increased to 425 pages by some twenty appendices, while 31 large plates are also included.

It is a document of such great engineering interest that many of our readers will desire to secure a complete copy of the report, and we take this opportunity to recommend prompt application by those in charge of engineering reference libraries, as only a limited edition has been printed and copies are likely to be difficult to procure.

We reprint below a summary of those features of the report of greatest interest and follow it by a condensed reprint of the Majority report. The Minority report will be given in our next issue:

In view of the fact that the lock canal project recommended by the minority of the Board has been approved by the Canal Commission and the President, and appears to be, in all probability, the plan on which the canal will actually be built, it is of even more interest than the sea-level project. This is particularly the case because the lock-canal project recommended by the minority differs radically from any plan that has been heretofore considered.

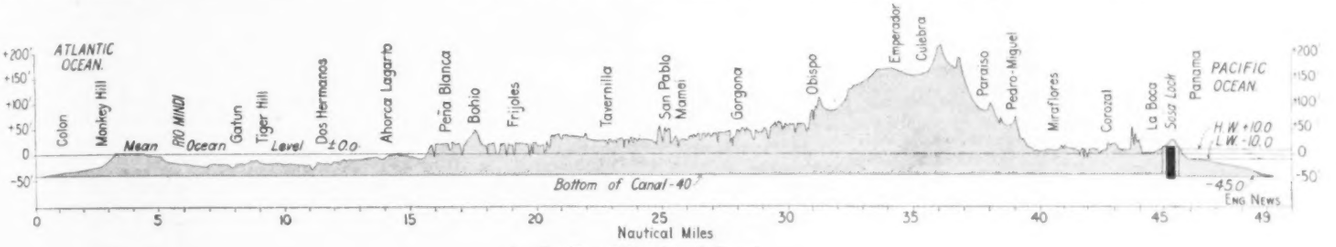
on the Atlantic side and to Miraflores on the Pacific side.

Reference may here be made also to an important change in alinement at the Atlantic end on which the entire Consulting Board were agreed. As shown by the map, Fig. 1, the canal entrance is to be straight through Limon Bay. The sharp reverse curve around Cristobal point at the entrance of the canal, which has existed in all previous plans, is eliminated and the length of canal excavation is reduced by several miles. As some of our readers may remember, bids were actually called for on the harbor improvement at Cristobal last spring under the Walker Commission, but were fortunately rejected, postponement being made until the Board of Engineers could have an opportunity to pass on this feature. The urgent importance of this change was first brought to public attention by Major Gillette in our issue of July 27 last; and: "the Board has adopted a line for the canal from Gatun to deep water, which is practically the one recommended by Major Gillette"—to quote verbatim from the report.

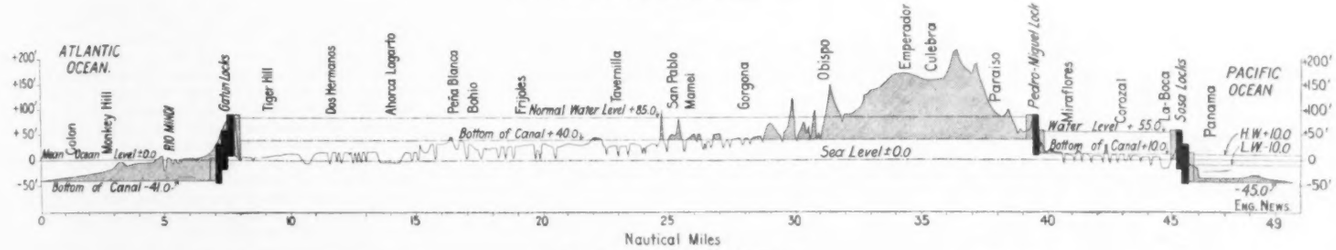
The total volume of excavation for the sea-level plan is estimated at 231,000,000 cu. yds., of which 110,000,000 yds. is in the Culebra cut, 8 miles long. For the lock canal project the total

taken the construction of two great steamships, 800 ft. long, with 88 ft. beam and with 36 ft. draft. These two vessels, while they are little likely ever to pass through the Panama Canal, have made necessary a radical increase in its dimensions to conform to the law. The canal cross-section adopted by the Board for the sea-level plan is 40 ft. in depth and 200 ft. in width in rock sections and 150 ft. in "firm earth" sections. For the lock canal project, the cross section of the canal through Culebra cut is the same as for the sea-level plan; but nearly all the rest of the distance is in open lake navigation or channels much broader than those necessary in the sea-level plan. As to the lock dimensions, the sea-level supporters fixed on a chamber 1,000 ft. in length and 100 ft. in width, with 40 ft. depth over the meter-sills. The lock canal project, however, reduces these dimensions to 900 ft. length and 95 ft. width, which are held to be amply sufficient for all requirements that can reasonably be anticipated.

The most interesting engineering work in the lock canal project is the great dam at Gatun, which will be the largest earth dam in the world. It will be, as shown by the plan, Fig. 4, 7,700 ft. in length and 2,625 ft., or nearly half a mile in extreme width. Its top, as shown in Fig. 7, will



A. Profile of Sea-Level Canal.



B. Profile of Lock Canal.

FIG. 2. COMPARATIVE PROFILES OF SEA-LEVEL CANAL AND 85-FT. SUMMIT LEVEL LOCK CANAL.
(Shaded Area in Each Profile Shows Material to Be Excavated.)

It most nearly resembles the plan proposed by Major Cassius E. Gillette, U. S. A., in Engineering News of July 27, 1905; and coincides with that plan in locating a high dam at Gatun, nine miles down the Chagres Valley from Bohio, creating a great fresh-water lake over a hundred square miles in area and deep enough for ocean vessels to sail clear up to the cut through the Culebra divide with very little excavation. The level of this lake extends through the Culebra cut and a descent of 30 ft. is then made by a lock at Pedro Miguel into an artificial lake formed by a dam across the Rio Grande Valley at La Boca. A flight of two locks at Sosa will pass vessels from this lake to the waters of the Bay of Panama.

Reference to the comparative profiles of the Sea Level and Lock Canal Projects in Fig. 2 will show how great is the contrast between the two in the amount of material to be removed. Further, this lock canal project adopts to a considerable extent the chief advantages of the "Terminal Lakes" plan of canal construction as advocated by Mr. Lindon W. Bates, and in our columns in December last by Mr. Wm. Ham Hall. As the profile shows, there is practically no excavation necessary with this project except through the summit divide and for about five miles at the Atlantic end from the Bay of Limon to the Gatun locks. A glance at the profile of the project approved by the Commission of 1901 (Eng. News, Dec. 14, 1905, p. 618) will show how greatly the excavation is reduced by the new plan as compared with the older plan by which the sea-level channel was carried up to Bohio

quantity of excavation in the Culebra cut is reduced to less than 54,000,000 cu. yds. It is estimated that the construction of the Gatun locks, which will require 3,660,000 cu. yds. of excavation and 1,300,000 cu. yds. of masonry, will take about as long a time as the excavation of the divide cut.

The total estimated cost of constructing the lock canal recommended in the minority report is in round numbers $140,000,000; and the time necessary is estimated at 7½ to 9 years. In comparison, the estimate of the majority of the Board for its sea-level project is $247,000,000, and from 12 to 15 years is the estimate of time required for its construction.

It should be stated here, however, that both these estimates are for a much deeper and wider canal than any heretofore contemplated. This increase in dimensions is made necessary by the wording of the Spooner Act, which provides that the canal "shall be of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use, and such as may be reasonably anticipated."

The Isthmian Canal Commission of 1901 proposed a canal with a bottom width of 150 ft. and a depth of 35 ft. This was, it may be noted, a great increase over the original De Lesseps project, which was for a canal 29.5 ft. deep with a bottom width of 72 ft. The lock chamber adopted by the 1901 commission was 84 ft. in width and 740 ft. in length.

Since 1901 the Cunard company has undertaken the construction of two great steamships, 800 ft. long, with 88 ft. beam and with 36 ft. draft. These two vessels, while they are little likely ever to pass through the Panama Canal, have made necessary a radical increase in its dimensions to conform to the law. The canal cross-section adopted by the Board for the sea-level plan is 40 ft. in depth and 200 ft. in width in rock sections and 150 ft. in "firm earth" sections. For the lock canal project, the cross section of the canal through Culebra cut is the same as for the sea-level plan; but nearly all the rest of the distance is in open lake navigation or channels much broader than those necessary in the sea-level plan. As to the lock dimensions, the sea-level supporters fixed on a chamber 1,000 ft. in length and 100 ft. in width, with 40 ft. depth over the meter-sills. The lock canal project, however, reduces these dimensions to 900 ft. length and 95 ft. width, which are held to be amply sufficient for all requirements that can reasonably be anticipated.

The most interesting engineering work in the lock canal project is the great dam at Gatun, which will be the largest earth dam in the world. It will be, as shown by the plan, Fig. 4, 7,700 ft. in length and 2,625 ft., or nearly half a mile in extreme width. Its top, as shown in Fig. 7, will be 100 ft. wide and 50 ft. above the water level of the lake. It will be founded on an indurated clay, which, as shown by the borings in Fig. 6, is found at moderate depth over most of the area covered by the site. It is agreed by all the members of the Board that the conditions at this site as developed by the latest borings are more favorable than at Bohio, where all previous official projects for a lock canal have located a dam. The water level in the great lake, 110 sq. miles in area, which this dam will create will be controlled by Stoney sluice gates similar to those in use at the Chicago Drainage Canal regulating works. These will be capable of discharging a volume of 140,000 cu. ft. per second when the lake is 1 ft. above the normal water level, and will be able to keep the water level constant with a maximum variation in the greatest floods of not more than 2 ft. The estimated cost of the Gatun dam and regulating works is $7,788,000, which may be compared with $7,579,000 estimated for the Bohio dam and Gigante spillway in the project of 1901, or $6,000,000 estimated for a dam at Gamboa in the sea-level project of the present Board.

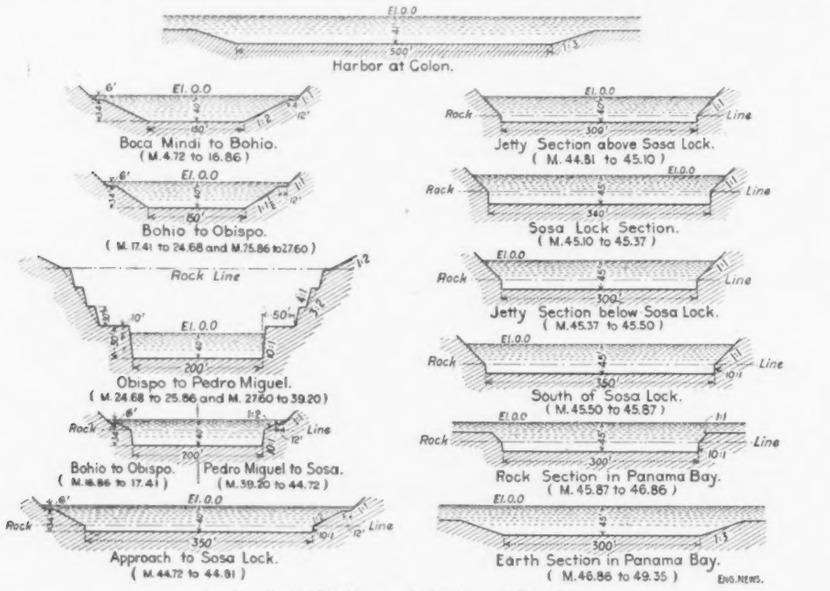
It is to be noted that the Gatun dam will also save, however, the nine miles of canal excavation and river diversions between Bohio and Gatun proposed in the 1901 project, making a net saving, after allowing $2,000,000 for reconstructing the Panama R. R., around Lake Gatun, of nearly $12,000,000.

The above summarizes briefly the most important features of the Board's report. In what

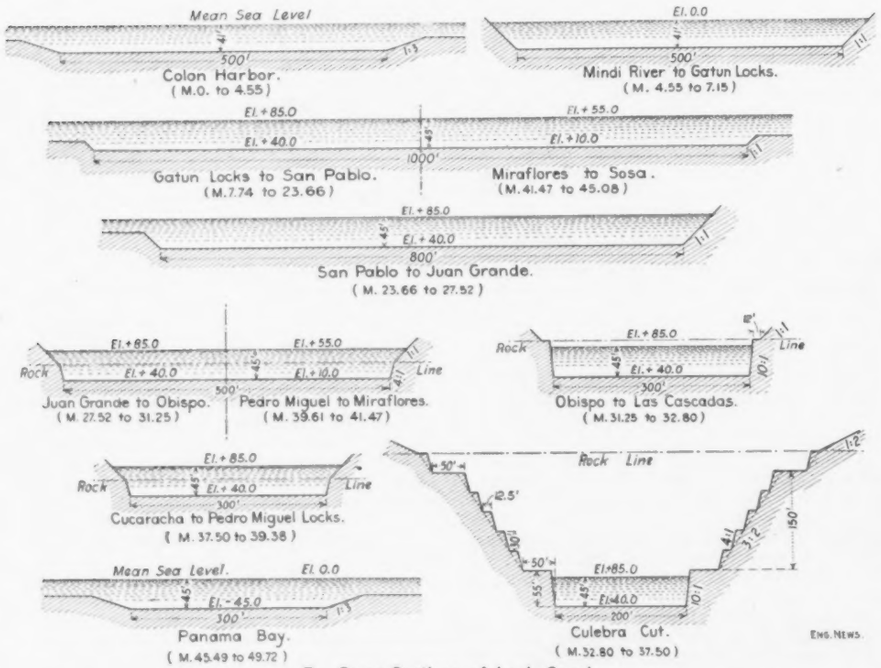
follows we have reprinted directly and abstracted some of the most interesting matter in the report, taking it up seriatim.

SUMMARY OF PROCEEDINGS.

The Board, made up of 12 engineers, was appointed by the President on June 24 and met in Washington on Sept. 1. (The make-up of the Board was fully given, with biographies of its members, in Engineering News of Sept. 14.) The Board held 30 regular meetings and paid visits to the Wachusett dam and the North Dike of the


El. 0.0
500'
Harbor at Colon.
Boca Mindi to Bohio.
(M. 4.72 to 16.86)
Bohio to Obispo.
(M. 17.41 to 24.68 and M. 75.86 to 27.60)
Obispo to Pedro Miguel.
(M. 24.68 to 25.86 and M. 27.60 to 39.20)
Bohio to Obispo.
(M. 16.86 to 17.41)
Pedro Miguel to Sosa.
(M. 39.20 to 44.72)
Approach to Sosa Lock.
(M. 44.72 to 44.91)
Jetty Section above Sosa Lock.
(M. 44.81 to 45.10)
Sosa Lock Section.
(M. 45.10 to 45.37)
Jetty Section below Sosa Lock.
(M. 45.37 to 45.50)
South of Sosa Lock.
(M. 45.50 to 45.87)
Rock Section in Panama Bay.
(M. 45.87 to 46.86)
Earth Section in Panama Bay.
(M. 46.86 to 49.35)
ENG. NEWS.

A. Cross-Sections of Sea-Level Canal.


Mean Sea Level
Colon Harbor.
(M. 0. to 4.55)
El. 0.0
Mindi River to Gatun Locks.
(M. 4.55 to 7.15)
El. + 85.0
El. + 40.0
Gatun Locks to San Pablo.
(M. 7.74 to 23.66)
El. + 55.0
El. + 10.0
Miraflores to Sosa.
(M. 41.47 to 45.08)
San Pablo to Juan Grande.
(M. 23.66 to 27.52)
Juan Grande to Obispo.
(M. 27.52 to 31.25)
Pedro Miguel to Miraflores.
(M. 39.61 to 41.47)
Obispo to Las Cascadas.
(M. 31.25 to 32.80)
Cucaracha to Pedro Miguel Locks.
(M. 37.50 to 39.38)
Rock Line
El. - 45.0
Panama Bay.
(M. 45.49 to 49.72)
El. 85.0
El. 40.0
Culebra Cut.
(M. 32.80 to 37.50)
ENG. NEWS.

B. Cross-Sections of Lock Canal.

FIG. 3. COMPARATIVE CROSS-SECTIONS OF NAVIGATION CHANNELS OF SEA-LEVEL CANAL AND LOCK CANAL.

Boston water-works and sailed for the Isthmus on Sept. 28. The work of the Board was done partially through committees. The committee on the preparation of plans for a sea-level canal was made up of the Chairman, Gen. Davis, and Messrs. Guerard, Hunter, Burr, Parsons and Quellennec. The committee on lock canal plans was made up of the chairman and Messrs. Stearns, Tincauzer, Ripley, Abbot and Noble. The latter committee submitted four projects to the Board, two with 85-ft. summit levels (of which one was afterward approved by the minority of the Board), and two with 60-ft. summit level. Of these it was decided by a vote of 8 to 5 to select the plan with a 60-ft. summit level, with one lock each at Gatun, Bohio, Pedro Miguel and Sosa, for comparison with the sea-level plan. By the same vote, the sea-level plan was finally adopted.

PHYSICAL CHARACTERISTICS OF THE PANAMA ROUTE.

The tidal oscillation in Limon Bay, the initial point of the canal route, is about 2 ft., while at Panama it is about 20 ft. The harbors are not naturally good, but they have been made to suffice for the limited traffic seeking this route.

The Chagres is a torrential stream, and drains a basin of an estimated total area of about 1,200 square miles.

At Alhajuela the low-water surface of the river is about 95 ft. above sea level, and at the mouth of the Obispo 45 ft.; but at Bohio, 13 miles farther down, it is practically at sea level. From Bohio to the sea the surface of the ground for considerable areas in the vicinity of the river is but little above sea level.

There are several notable topographic features of the Chagres Valley which have a very important bearing upon the canal problem. In the upper courses of the stream and its tributaries the bottom in the waterway is the original rock formation, and the channel is strewn with boulders, pebbles and sand which have been loosened by erosion. It is found that at Alhajuela there is a depth of about 29 ft. of gravel overlying the rock in midstream. The rock outcroppings in the bluff appears to be of a firm and homogeneous structure, of volcanic origin. At this point the hills on either side contract the valley in a marked degree. At Gamboa, which is just above the junction of the Obispo, the gravel covering of the rock bed is about 50 ft. in depth. At Bohio the rock is 105 ft. below tide level, and the drills penetrated wood at various depths to 150 ft. At Gatun the depth to what in this report is sometimes classed as rock—an indurated sandy clay—is 258 ft. in the deepest place, and at another, on the same section, the depth of the sand, clay, gravel, etc., is about 240 ft. Here also buried wood was brought up by the drills.

The general aspect of the central isthmus is one of great irregularity—the hills are numerous and have very steep slopes, while the valleys are narrow. Culebra is one of these hills, its summit being some 700 ft. above the sea. The greater part of the material is of volcanic origin, the central masses of the hills containing hard volcanic rock and dikes of basalt.

Between, above and below these hard-rock masses are softer rock and dark, indurated clay, while the upper covering of the superficies is composed of the same volcanic material, but much changed by exposure to the weather, and where cut through, as it is by the canal excavation all the way for seven miles through the dividing ridge, the covering is seen as a red clay, occasionally containing boulders, having a varying thickness to 30 ft. and at one place to more than 40 ft., but generally its thickness is but 10 to 20 ft. It is in this top layer of reddish clay that all the larger slides have taken place.

The rock near the surface a few miles from the oceans is conveniently situated for foundations for locks, dams, etc., and is sufficiently dense to make good concrete material, while sand suitable for use in masonry structures is found in great abundance on the beaches of Panama Bay, and probably that found in some of the gravel beds in the Chagres will also be suitable for the same purposes.

SANITATION AND HYGIENE.

The construction of the Panama Railroad was undertaken in 1850. Workmen from the United States who were entirely unacclimatized were employed in large numbers and many succumbed to the local fevers, others to exposure and diseases due to intemperance and disorderly living.

It has been often stated that the mortality among the railroad workmen reached an aggregate which equaled in numbers the cross-ties used in the railway roadbed—that is to say, 150,000—but the chief engineer of that road, the late Col. George M. Totten, stated repeatedly that the total number of persons employed in building the road never exceeded 7,000 at any one time, and that the number of laborers and workmen who died in the whole five years did not exceed 1,200 in all.

Work on the canal was begun in 1881. In 1882 the force employed was 1,910, and in 1884 the average number for the year was 17,615, although the maximum was 19,243, in October. The aggregate of the numbers of those reported yearly as employed in the whole period is 86,812, or an average of 10,881 per year. By computation it is found that the total number treated for sickness during the eight years was 52,814. It is also found that the number of deaths of employees in the same period was 5,627, showing a rate of mortality among the sick of 10.62%, and among the employed of 6.48%.

The methods adopted by the health authorities on the Isthmus twenty years ago for combating tropical diseases which caused great sickness and mortality were such as were deemed most effective by the sanitarians of the period. The French company erected fine hospitals of large capacity, with up-to-date equipment, and their physicians and nursing force were competent and efficient, but modern methods for preventing sickness were then unknown. Yellow fever was believed to be due to a poison, ever present, to which a certain proportion of newcomers, especially Europeans, was expected to succumb, as they had always done. It was believed that the disease was contagious and that the malady was transmitted by personal contact with the sick or their excreta, and the preventive measures employed to protect the new arrivals consisted of attempts at isolation of the sick, as is now done with those afflicted with smallpox.

Malaria was believed to be caused by a miasma exhaled from the soil or by decaying vegetation, and it was accepted that newly upturned soil caused the disease to spread. As the name implies, the disease was believed to be due to bad air. But discoveries of the very greatest importance to the human race have put an end to these misconceptions, and malaria and yellow fever are no longer a mystery to science. The mosquito theory of the transmission of these two diseases is now generally accepted as the solution of the mystery by all the leading sanitarians and physicians.

The yellow fever record on the Isthmus since the United States took over the canal works is as follows: In May,

1901, there was 1 case; in June, 1; in July, 2; August, none; September, 1; October, 1; November, 3; December, 6; January, 1902, 18; February, 14; March, 11; April, 9; May, 52; June, 62; July, 42; August, 27; September, 7; October, 2; November, 5, one of which was from a point 20 miles distant, making a total in the 19 months of 246 cases. Of these, 84 terminated fatally, or about 34%.

Commenting upon these figures, Col. W. C. Gorgas, U. S. Army, the chief sanitary officer of the canal works at Panama, remarks in his October report as follows:

I consider this (the October record) as indicating the near approach of the disappearance of the disease. * * * The only yellow fever period when there was anything near to approximating as many non-immunes on the Isthmus as we have at present was at the time during the French regime, when they had their maximum force. This occurred in October, 1884, when they had 19,243 men on their rolls, of whom 2,706 were non-immunes. Among these they had 21 deaths from yellow fever in that month and approximately 84 cases. During October of this year our force has also reached its maximum, about 22,000,* of which number about 4,000 are non-immunes. Among these 4,000 employees we had not a single death from yellow fever and only a single case. Of the three cases occurring on the Isthmus, two were people not employees of the Commission.

Here we are comparing two periods in which there was a large number of non-immunes present—the same season of the year and the same climatic conditions generally—the only difference being that in the year 1905 modern tropical sanitary methods were enforced all over the Isthmus by some 2,200 men. * * * Twenty years ago these methods were unknown, malaria and yellow fever were a mystery to science, and our predecessors were unable to do anything for their control.

The results obtained, I maintain, are solely and entirely due to the sanitary measures put in force. And be it remembered at the same time that we have at present with us fully one-third more people subject to yellow fever (non-immunes) than the French had in October, 1884.

* * * * * * * *

The showing with respect to the sick rate of employees generally is very good. Among 22,000 men we have a daily average of about 450 in hospital. This gives us a constant sick rate of 21 per 1,000. We could not hope to show a lower rate than this if our canal were being dug between Washington and Baltimore. I am inclined to think that the sanitary question of Panama has been settled, as we have shown that a force of laborers as large as we are likely to have and as unfavorably situated as they ever will be can work on the Isthmus without suffering from yellow fever, and that the general health of this same force can be kept as good as if they were digging a canal in a healthy part of Maryland.

A few years ago the abandonment, as a canal headquarters, of the city of Ismailia, situated on the line of the Suez Canal, was seriously considered because of the general sickness of the European inhabitants and the canal officials. The population was 9,000, of which the European inhabitants were 2,000. Among these there were 1,400 cases of malarial fever annually, of which many resulted in death. The mosquitos (anopheles) were killed and their breeding places destroyed in 1902. The number of cases of malaria since has been, yearly, 214, 90, and in ten months of 1905, 46, with no deaths. Those who have had malaria subsequent to the sanitating of the place are those who had been chronic sufferers from the disease previously.

To the ordinary observer the appearance of the city of Colon is much worse than that of Panama, yet its record for disease is better. Yellow fever has been comparatively rare there. Its better record may be due to its situation on an island, the surface of which is awash with sea water throughout a considerable part of its superfices. We are told by the sanitary officers that the mosquitos which cause yellow fever and malaria do not breed in salt water. This has significance and weight in determining the general drainage system for the canal works.

The discovery of the probable cause of yellow fever, and the knowledge of the measures adopted by sanitarians to control and prevent its ravages, have simplified the task of those who are to make the canal.

The United States not only has the right granted by treaty to enforce all necessary rules of sanitation and for the preservation of order, but the authorities of the Republic of Panama have shown the most ready willingness to co-operate and assist in the efforts taken to rid the Isthmus of disease and prevent its importation.

Notwithstanding the fact that near-by Pacific ports have for several years been infected with bubonic plague, the health officers of the Canal Zone have, by means of a rigid quarantine, so far prevented this pest from obtaining a foothold on the Isthmus, and there seems to be good reason for the confidence of these officers in their ability to exclude that disease permanently.

WORK DONE AND PRESENT CONDITIONS.

The present state of the canal work is but little different from that in which the old Panama Canal Company left it in 1889. The present condition of the seven-mile cut through the continental divide shows that a large amount of material has been excavated in that locality, principally by the old company, but to the extent of about 7,000,000 cu. yds. by the new company and nearly 1,000,000 cu. yds. by the Isthmian Canal Commission during 1904-5. The maximum depth of this cutting below the original surface —333 ft. above sea level—is about 165 ft. The excavated material has been deposited mainly in the Lirio marsh, about a mile northeast from the deepest part of the cut, and to a less extent in the Rio Grande Valley near Cucaracha, immediately south of the southerly end of the cutting.

*Including those employed on the Panama Railroad.

A total amount of about 80,000,000 cu. yds. of all classes of materials has been excavated throughout the entire line of the canal, making almost continuous work from one end to the other. By far the greater portion of this excavation was soft material or earth largely removed by dredges, but a comparatively small portion of it may be classed as rock. This means that the principal portion of the remaining material to be taken out must be considered rock, and much of it as hard rock. A substantial portion of this 80,000,000 cu. yds. of excavation has been so deposited along the proposed line of canal that it will have to be again moved in the work of construction, because of the greatly increased cross section of prism now required.

It is difficult if not impossible to state what portion of this excavation will be available in future construction. The entire excavation made at the divide is of this useful character, but it is probable that the aggregate of all the useful portions of the work done will not exceed 40,000,000 cu. yds.

PROJECTS BROUGHT BEFORE THE BOARD.

Four pages of the report are devoted to the "Terminal Lakes" plan for the canal ably advocated by Mr. Lindon W. Bates. The conclusion reached by the Board is that Mr. Bates' plan A for a canal with a summit level of 27 ft. would be inferior to a sea-level plan and would involve nearly as great a cost. Of his plan with a summit level of 62 ft., it concludes that the cost at the unit prices adopted by the Board would be greater than for the Board's 60-ft. lock canal project with no corresponding advantages. A difficulty with Mr. Bates' "terminal lakes" plan is that a great area of the most valuable land in the Canal Zone would be flooded, making an enormous outlay for land damages necessary.

Mr. P. Bunan-Varilla brought before the Board a plan for a lock canal with a summit level of 130 ft. to be gradually deepened by dredging while in use to a sea-level canal. The Board finds that the proposed enlargement of the lock canal would involve the excavation under water of a vast amount of rock, much of it at depths as great as 40 to 50 ft. It concludes that the cost of such work would be so great as compared with the cost of rock excavation in the dry, that a sea-level canal made in this way would cost at least $100,000,000 more than if made in the ordinary manner.

Major Cassius E. Gillette's plan, published in Engineering News of July 27, 1905, was brought before the Board and, as stated above, his recommendation of a relocation of the Atlantic terminus was adopted, while his proposed location for a dam at Gatun is practically adopted in the minority report, although the dam differs radically from the one which Major Gillette proposed, his plan for cutting off seepage underneath by sheet piling not being considered necessary. The Board admitted also the force of Major Gillette's criticism of the earlier plans for a Gamboa dam with a masonry core wall and earth fill.

THE 60-FT. SUMMIT LEVEL PROJECT.

This plan, adopted provisionally by the majority of the Board for comparison with the sea-level project, proposed an earth dam at Gatun, raising the water-level to 30 ft., and a second dam at Bohio, raising it to 60 ft. At Gamboa a dam for the control of the Chagres would be built identical with that for the sea-level canal. On the Pacific side the descent would be made by one lock at Pedro Miguel and one at Sosa. The cost of this canal, including 20% for contingencies, was estimated at $176,000,000.

The Majority Report Recommending a Sea-Level Canal.

SAFETY AND PROTECTION.

The general question of defense of the Isthmian transit will be in no way affected by the type of the canal.

Dismissing, then, any consideration of the question of general military defense, the Board is of the opinion that the safety and protection of the canal will be sensibly influenced and affected by its type.

The modern lock for ocean-going vessels is a work which an enemy, through stratagem, could with no great difficulty put out of use in an hour or in even a few minutes. If a small detachment from the enemy's fleet, armed with high explosives, landing secretly by night at some nearby shore or inlet, hiding in the neighboring jungle, should surprise the canal guards, or if a few malicious individuals in disguise should succeed in exploding against a lock gate under high water pressure as much explosive as they could carry, they could disable the lock, and could probably cause damage of such colossal magnitude as would put the canal out of use for months. This danger is one that very strict watch and guard might prevent in great measure, but it is well-nigh impossible to provide effectually and always against such peril. Sovereign rulers, bridges, railway trains, buildings, and ships, all under very strict watch, have been destroyed by lawless individuals. Guards would, of course, be always on duty at the danger points, and every protective measure possible would be adopted, but if a few desperate characters should set out to disable the canal, and persist in the attempt, regardless of consequences to themselves, the peril would be very great.

As respects vulnerability of the canal or its works to injury and interruption of traffic by a few lawless individuals, the means and results are not difficult to foresee and estimate.

(a) The wrecking by explosives of the lock gates while under unequal water pressure, or of the valve chambers where the lock filling and emptying mechanism is situated: The remedy in the one case would consist in the removal of the wreckage and the replacement of the gates; in the other, in possible very extensive repairs requiring much time. If the controlling gates of an upper lock should be destroyed, the summit level would be drained, and if the gates were wrecked so as to afford a free outlet to the water, the locks below and the canal itself would be ruined or at the least greatly damaged. In case the gates or controlling mechanism of a lock were ruined, and free exit for the upper waters was permitted through the chamber, the lock alongside would also be emptied and put out of commission until its neighbor was repaired.

(b) The blowing up in a lock of a vessel offered for transit, but designedly laden with high explosives for ignition at the proper moment: In that event the lock would be destroyed, and if it was a lift lock, a year or more would be required for repairs.

(c) The detonation of some high explosive against or under some portion of a dam built to maintain a summit level: This would be a much more difficult undertaking and one less likely to be attempted. The wrecking by explosives of the controlling and discharging sluices in dams would be easier, but a good many men and considerable time for a successful operation would be necessary. This might be a serious jeopardy at one point for a sea-level canal, but provisional repairs with timber could always be quickly effected.

(d) The sinking of a large vessel in the canal prism by any means: Recently the steamship Chatham, of 2,500 tons displacement, laden in part with blasting gelatin, met with an accident in the Suez Canal and later was sunk. It had to be blown up and removed before transit could be resumed. The time during which the canal was closed to vessels was ten days. In case of a similar incident at Panama, whether resulting from an accident as at Suez or from design, the consequences, so far as interruption of transit is concerned, might be expected to have a similar result.

The plan proposed by the Board for the isthmian transit will have twin tidal locks near the Pacific terminus, which, if disabled, one or both, as under (a), would still be usable (after removal of wreckage) for a part of each day (the period of spring tides) in each lunar month, and probably throughout the whole twenty-four hours during the remainder of the lunar month (neap tides).

The plan also contemplates a dam at Gamboa for Chagres control, provided with regulating sluices. There are to be three small dams for the control of minor streams, but there are to be no lift locks, for these, it is claimed, both single and especially in flight, are much more vulnerable than any other essential accessory that has been proposed to be used in any type of canal that has been considered by the Board, and this jeopardy is considered to be a very grave one.

TRANSFORMATION OF A LOCK CANAL INTO A SEA-LEVEL CANAL.

The instructions of the President to the Consulting Board under date of September 11, 1905, contain the following inquiry:

I desire also to know whether, if you recommend a high-level multi-lock canal, it will be possible after it is completed to turn it into, or to substitute for it, in time, a sea-level canal without interrupting the traffic upon it.

The Board is of opinion that it is possible to transform a lock canal into a sea-level canal without material interruption of traffic and without serious delays to navigation, although the operation would not be an easy one, nor can a trustworthy estimate of its cost be made at the present time. The work evidently involves the excavation of immense quantities of rock and earth, much of it at depths considerably exceeding 40 ft. below the surface of the water.

An approximate estimate of cost of reducing a lock canal with a terminal lake on the Atlantic side formed by a dam at Gatun, with three locks on the Atlantic side and three on the Pacific, and with a summit level 85 ft. above mean tide, to a sea-level canal with the dimensions of prism adopted for the sea-level plan, has been made, and amounts to $209,000,000.

After a full and careful consideration of all phases of this question, the Board has reached the following conclusions:

1. That it is possible to turn any lock canal which it has considered into a sea-level canal without interrupting the traffic upon it.

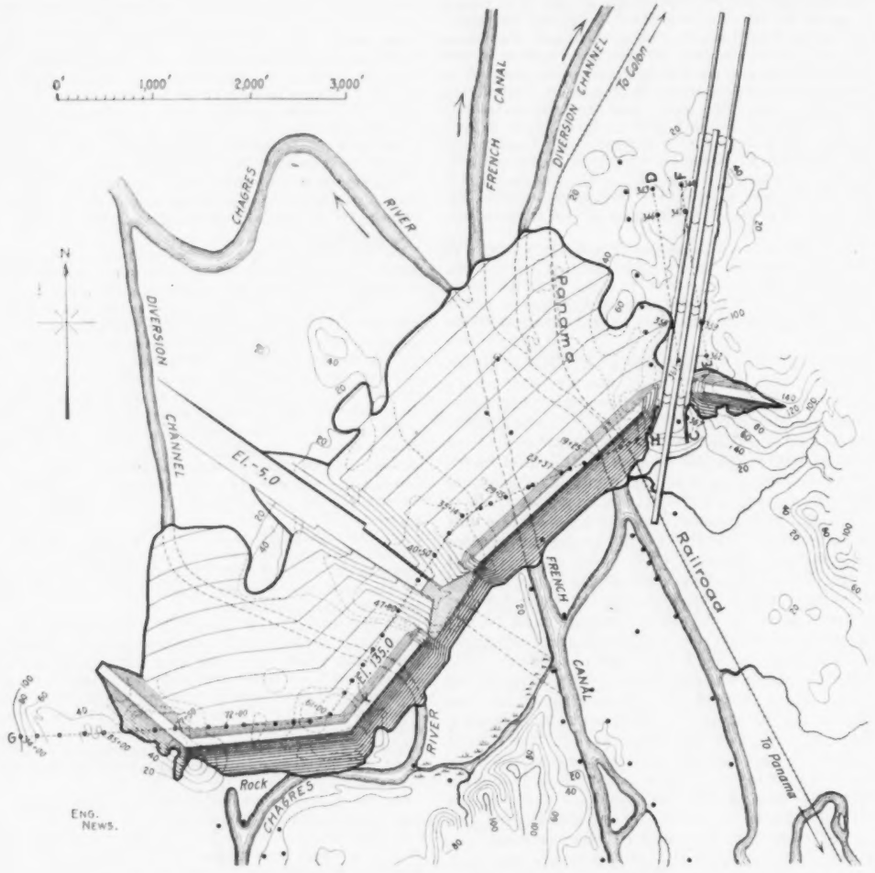


FIG. 4. PLAN OF EARTH DAM AND FLIGHT OF THREE LOCKS AT GATUN.

2. That it is practicable from an engineering standpoint to transform any lock canal which it has considered into a sea-level canal; but that the cost and difficulty of such transformation would be so great as to render such a change impracticable from a financial standpoint until the traffic should have so increased as to tax the capacity of the lock canal, or until other good and sufficient reasons existed for such a change.

3. That if a sea-level canal is to be constructed in the near future it should be built directly without first building a lock canal.

CAPACITY OF CANAL FOR TRAFFIC.

Having noted that steamers of a length of 740 ft. over all and a breadth of 75 ft. are at present engaged in ocean navigation, while vessels of a length of 800 ft. by 88 ft. in breadth are now actually being built, and having the assured opinion that naval development has by no means come to an end, the Board arrived at the following conclusions:

1. That the locks on a canal of any type should be of such usable dimensions as will afford a length of 1,000 ft., a breadth of 100 ft., and a depth of 40 ft.

2. That the prism of the canal for the length to be excavated through the divide (i. e., the length usually known as Culebra cut) should have a depth of 40 ft., a bottom width of 200 ft., and sides with slopes of about ten vertical to one horizontal.

A just estimate of the growth of traffic on the Panama Canal can not be formed from the statistics of the growth of trade on any existing waterway. The unprecedented increase in the population of the world which has taken place as civilization has advanced—it is generally agreed that the civilized population of the world was doubled in the course of the nineteenth century—and the movement of the surplus population westward, i. e., from Europe to North and South America, must be of necessity not only proceed but proceed at an accelerated rate, so that the growth of trade on the interoceanic highway will not be, as in the case of the Suez Canal, merely due to the expansion of the volume of commerce which takes place year by year as facilities are presented for the movement of commodities, but to that expansion multiplied by the increasing requirements of a constantly expanding industrial population.

THE CONTROL OF THE CHAGRES AND OTHER STREAMS.

The Chagres has been considered to be an element of great difficulty in the construction of the Panama Canal from the earliest stages of discussion of the project.

Observations, more or less complete, of the discharge of the Chagres River at Gamboa have been maintained from 1882 to the present time. Its flow in the dry season may fall to less than 300 cu. ft. per second, while in the flood of 1879 it is supposed to have risen for a short period to nearly 80,000 cu. ft. per second.

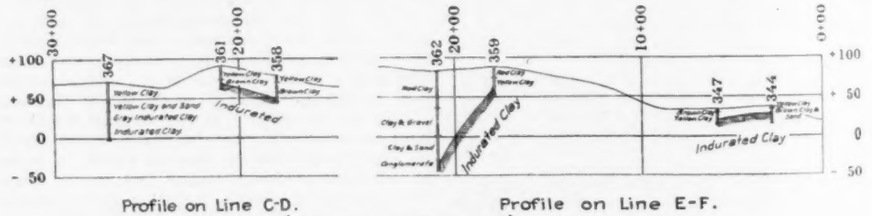
There have been but six severe floods in [illegible] a century, and these floods are of short duration. A discharge in excess of 20,000 cu. ft. per second has never been observed to last more than 58 hours, although that limit may have been exceeded in 1879.

If a dam be constructed at Gamboa with an elevation of its top at 180 ft. above mean sea level, or 150 ft. above the river bed, and if the highest flow line of that reservoir be taken at 170 ft., the area included within that flow line will be 29.47 square miles. With the minimum depth of water of 40 ft. provided for the sea-level canal, the minimum wetted cross section would have an area of over 8,000 sq. ft., so that if 15,000 cu. ft. of flood water per second from the Chagres be permitted to enter the canal prism at Gamboa, the resulting current, if the entire quantity admitted flows in one direction, will be but one and one-fourth miles per hour, a negligible quantity so far as its effects upon navigation are concerned; but the plans for a sea-level canal contemplate a provision which would permit the discharge through the canal prism and regulating sluices near the tidal lock on the Pacific side of approximately one-third of this Gamboa discharge, and to that extent, at least, dividing the flow between the two oceans and consequently reducing the current velocity.

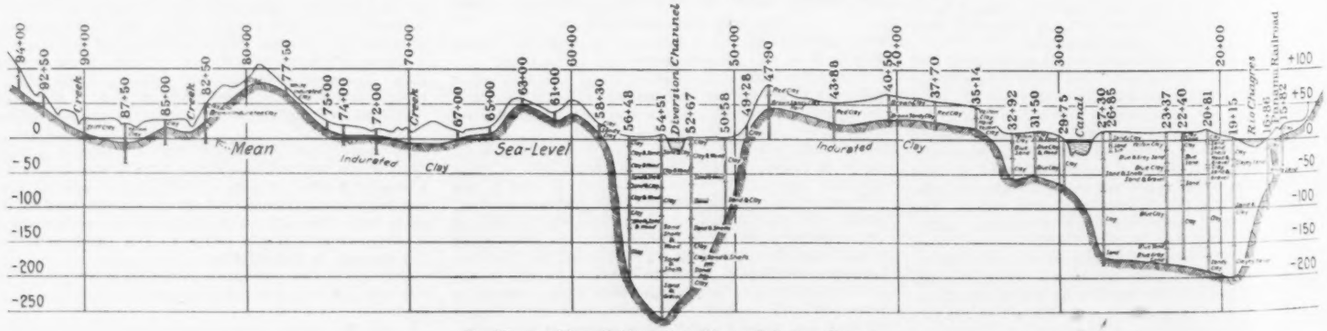
Computations demonstrate conclusively that the controlling capacity of the Gamboa Lake, as proposed by the Board, is ample for all the exigencies of flood flow which can ever occur in the Chagres River without any other regulating or controlling aid.

The elevation of water surface assumed at 170 ft. is sufficient to permit the use of an open channel between the Chagres watershed and the headwaters of the Gatun River for the discharge of surplus flood waters in that direction, should it ever be required. The controlling capacity of the Gamboa Lake, however, is so complete and satisfactory that the Board does not believe that it will ever become desirable to construct this open channel across the divide between the Chagres and Gatun watersheds.

The Gamboa Lake affords complete regulation and control of the Chagres River above Gamboa. It has already been stated that there are small streams now discharging into the Chagres River below Gamboa which must be taken care of during the construction of the canal. Ample provision has been made for the control of these smaller streams, either by utilizing the diversion channels planned by the old French company and now partially constructed or by constructing dams across their courses high enough to compel them to reverse their flow and discharge through the divides at the heads of their watersheds. Among the latter class are the Caño Quebrado and the Gigantito, the reverse flow of which would be discharged into the headwaters of the Trinidad and the Gigante, whose reverse flow would be turned into the basin of the Peña Blanca marsh and pass on to the sea through the



Profile on Line C-D. Profile on Line E-F.
(See Map of Gatun Dam.)



Profile on Line G-H. (See Map of Gatun Dam.)

FIG. 6. PROFILES FROM BORINGS AT SITE OF GATUN DAM.

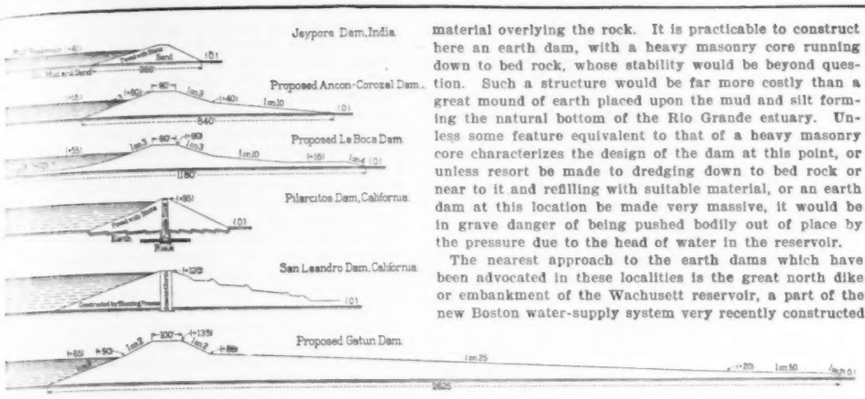


FIG. 7. COMPARATIVE CROSS-SECTIONS OF THE GATUN DAM AND OTHER GREAT EARTH DAMS OF THE WORLD.

Chagres channel and its existing diversion. The Gatun River (sometimes called the Gatuncillo) would discharge its waters and those of the Mindi through the Gatun diversion, nearly completed by the old company, into that part of Manzanillo Bay known as Puerto Escondido. After the completion of the canal the aggregate observed flood discharge of all the streams entering it below Gamboa—the Caño Quebrado, Gigante, and Gigantito being diverted as hitherto observed—would amount to less than 4,000 cu. ft. per second (see p. 240, Report of the Isthmian Canal Commission, 1901), a quantity that would exercise no material influence upon currents in the canal channel.

The tributary streams, whose beds at point of junction with the canal are considerably above the prism of the latter, will be discharged over masonry-stepped aprons or through metallic discharge pipes, or these beds will be sloped and lowered so as to prevent objectionable currents at junction points. The means for the accomplishment of these results are such as are in common use on nearly all important canals.

During three-fourths of the time these streams discharge an insignificant amount of clear water. When they are in flood they will bring down some silt, and it is recognized that the maintenance of the navigable canal channel will require a small amount of dredging.

DAMS.

The consideration of the projects presented by Mr. Bates, Major Gillette, and others has raised certain questions regarding the types of dams.

The earth dams which have already been built for the retention of large bodies of water, some of them exceeding 100 ft. in height, show that this type of structure may give satisfactory results when properly designed and constructed, but the character of the foundation material on which such dams are built and the means for preventing dangerous seepage underneath or through such foundations must always be carefully considered.

The subsurface material at Mindi and at Gatun, extending down to the hard indurated sandy clay or soft rock, attaining a maximum depth of 258 ft., is in large part of a comparatively fine character, consisting of sand and clay in varying portions and in various degrees of admixture, but the borings have also shown coarse sand and gravel with water flowing through it and out of some of the pipes used in making the examinations. As a presumption or speculation it may be stated as probable that most of this material under the weight of an earth dam would be so nearly impervious that only a small or negligible quantity of water would find its way through, even with the increased head of the reservoir; but that is simply conjecture.

It is more than possible, it is highly probable, if not certain, that at various points the material is sufficiently loose in texture to permit seepage or percolation in dangerous quantities. Nothing is more common in the sandy deposits of river valleys and in all sandy material than small passages or channels through which water moves, varying in size from thread-like openings to those sufficient to yield flowing wells of large discharge. Extended experience in dealing with the underground flow of subsurface waters in many places in the United States, and wherever investigations in that field of hydraulics have been made, shows this to be the case.

A careful consideration of these conditions of actual experience will show that any computations apparently indicating that the seepage or percolation taking place through a great geological profile like that at the sites of the proposed dams at Mindi, Gatun, Bohio, Gamboa, or at any similar location, are based upon assumptions without any warrant in engineering experience and involving the grave danger of excessive percolation under an earth dam.

The dam at La Boca between San Juan Point and Sosa Hill, unless carried down to bed rock at that location, would be placed upon a far worse foundation even than that proposed at Gatun or Mindi. The La Boca site is one covered by an ooze of mud and silt, with some sandy material overlying the rock. It is practicable to construct here an earth dam, with a heavy masonry core running down to bed rock, whose stability would be beyond question. Such a structure would be far more costly than a great mound of earth placed upon the mud and silt forming the natural bottom of the Rio Grande estuary. Unless some feature equivalent to that of a heavy masonry core characterizes the design of the dam at this point, or unless resort be made to dredging down to bed rock or near to it and refilling with suitable material, or an earth dam at this location be made very massive, it would be in grave danger of being pushed bodily out of place by the pressure due to the head of water in the reservoir.

The nearest approach to the earth dams which have been advocated in these localities is the great north dike or embankment of the Wachusett reservoir, a part of the new Boston water-supply system very recently constructed by Mr. F. P. Stearns, a member of the Board. In that case, deep and heavy sheet piling or deep excavation of the natural soil with refilling of suitable material was employed to prevent seepage or percolation wherever it was apprehended that the nature of the substrata was such as to permit it. It is the judgment of the Board that such safeguarding features as core walls, sheet piling, or the removal of unsuitable material should not be omitted in similar structures on this work of extraordinary magnitude and supreme importance.

The considerations of these and other reasons have prompted the Board to recommend at Gamboa either an earth dam with a heavy masonry core carried down to bed rock, or an all-masonry structure founded at the same depth and upon the same material.

THE SEA-LEVEL PLAN RECOMMENDED BY THE BOARD.

(A) ALINEMENT AND DESCRIPTION.

The width of the Isthmus at Panama is less than at any other point where it is feasible to construct a canal open throughout between the oceans. The width, less than 36 miles in a straight line, is only five miles greater than at the narrowest place, San Blas, but an open cut is impracticable there. The summit on the Panama route, which was 333 ft. above the sea originally, is lower than at any other known point between the Arctic Ocean and the Straits of Magellan, Nicaragua only excepted, while at the latter place, by reason of the greater distance between the oceans, the volume of material to be removed to form a lock canal is much greater than at Panama, and a sea-level canal is obviously impossible. At Panama alone is a sea-level canal in open cutting feasible, and the Board has no doubt of the practicability of such a canal.

The line adopted by the Board for the sea-level canal which it recommends for construction is in general that which was adopted by both the old and the new Panama Canal companies for their projects. While the Board approves this alinement for the purposes of ultimate construction, it believes that further examination should be made for the reduction of curvature and for other improvements of the line in detail, particularly at the deepest portion of the Culebra cut. It is believed that a judicious relocation between Emperador and Cucaracha will reduce the excavation considerably with only a comparatively small change of alinement. In this manner, at this particular portion of the line, excessive excavation on the easterly side of the deep part of the Culebra cut may be avoided, at the same time utilizing the entire volume of existing excavation between Emperador and Cucaracha.

At the Colon and La Boca terminals, however, it is the judgment of the Board that material changes should be made both in the plans of these terminals and in the alinement to eliminate considerable curvature.

The initial point of the axis of the canal is located in Limon Bay, about one mile northwest of Manzanillo light, at the beginning of the dredged entrance channel, where the depth of water is at least 40 ft. at low tide. From that point the axis of the dredged approach channel runs straight to near the southern limit of Limon Bay, where, near Mindi, a curve unites it with the center line of the canal, as partially completed by the old company. From Mindi the proposed line follows the partially excavated canal through the low marshy ground nearly to Bohio, a distance of 12 miles. The canal line first cuts the course of the Chagres River at Gatun, seven miles from Colon, and then repeatedly cuts it from that point to Bohio. The excavation throughout this entire distance from the sea channel to Bohio can be made by the simple operation of dredging, but there is some hard clay to be removed.

The deepest part of the summit cut at Culebra is about five and one-half miles from Obispo. The maximum depth of excavation required for a sea-level canal will be about 373 ft. below the original surface where the axis cuts the saddle. The deepest part of the present cut, however,

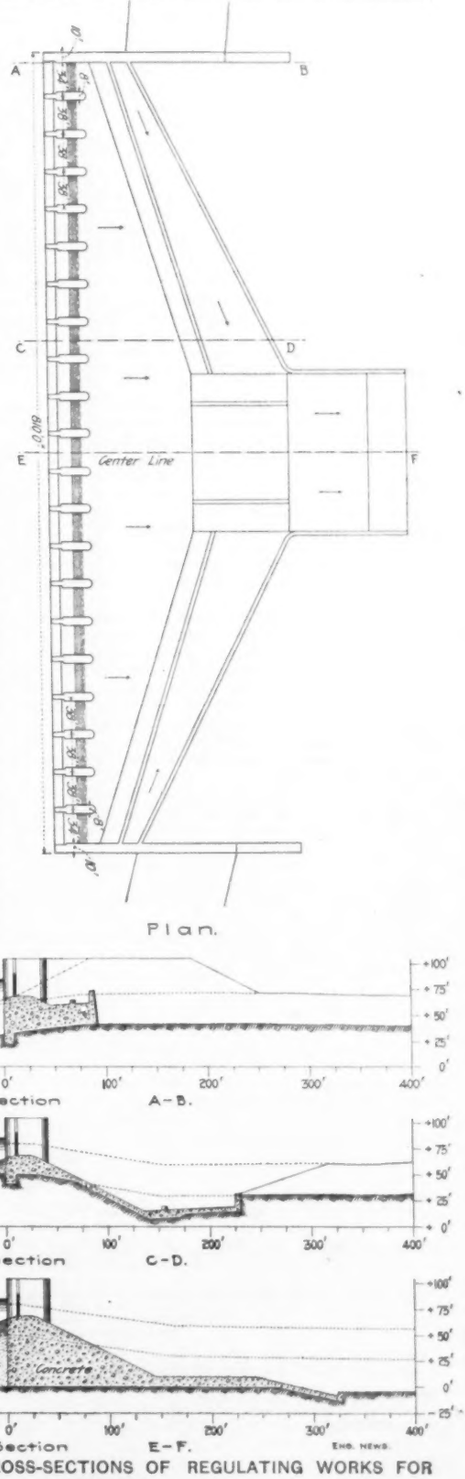


FIG. 5. PLAN AND CROSS-SECTIONS OF REGULATING WORKS FOR GATUN DAM.

is about 160 ft. below the original surface, or about 213 ft. above the bottom of the excavated channel required by the sea-level plan. The length of the main part of the great summit cut is about nine miles, from Obispo to Pedro Miguel. The material to be removed is partly of indurated clay so hard as to be classed as soft rock, and partly of hard rock with a surface covering of clay.

The canal line reaches low marshy ground nearly at sea level at a point about two miles below Pedro Miguel. From that point to deep water in Panama Bay the Board has adopted a different alinement from that of the French companies. The latter followed as closely as possible the course of the Rio Grande to its mouth at La Boca in order to avoid rock excavation, but that alinement included two curves which are avoided in the new location. The location recommended by the Board is practically a straight line from a point a short distance from Miraflores through the Rio Grande swamp; but opposite Corozal a low ridge or spur from the eastern highland is crossed, in which ridge the borings show rock. Advantage is to be taken of this conformation to locate on the rock foundation a wide spillway with regulating sluices primarily for discharging into the Rio Grande and so into the Pacific a part of the Chagres flow at Gamboa coming through the Culebra, but the sluices may also be used to regulate and reduce the currents in the canal while the tidal lock is open.

The canal continues in a straight line through the swamp to and through the saddle between Ancon and Sosa hills, where the tidal lock is to be placed, and thence to deep water off Isle Flamenco. From Miraflores to the lock the canal will be leveed, so as to prevent the tidal flow from entering it.

The French plan required a tidal lock at Miraflores some five miles from the bay shore, whereas in the new location it will be in the low Ancon-Sosa saddle, thus bringing it almost to the margin of the shore and avoiding the long approach channel wherein tidal currents would be generated if the locks for their control were at Miraflores, far inland.

Experience in the navigation of maritime canals shows that the area of the wet section of the prism must be at least four times that of the immersed section of the ship passing through it at a speed of six miles per hour. The smallest area of cross section of the canal prism, in rock excavation, exceeds 8,000 sq. ft. The dimensions adopted by the Board, therefore, will permit a speed of six miles per hour for the largest existing vessels using it, and of not less than eight miles per hour for the average ship. For a ship of 90 ft. beam and 38 ft. draft a speed of four or five miles per hour might be considered sufficient.

These speeds will enable ships of the largest size to pass through the canal in seven hours if the gates of the tidal lock at Panama are open, as they will be for more than half the time, or in eight hours during high spring tides, when the tidal locks will be in use. The time of passage of the average ship will probably be between five and six hours with the gates of the tidal lock open, or one hour longer when the tidal lock is in use. For a ship of the exceptional size given the time of transit might reach ten hours.

After the completion of the canal the tracks of the Panama Railroad can judiciously be placed on one of the berms of the canal, at least between Bohio and Miraflores, as the railroad will then lose its present character and serve local and passenger traffic only, besides being a tender to the canal for its maintenance and for other similar purposes. Power for operating it would be developed at the Gamboa dam.

The entire length of the line between shore lines is a little over 40 miles, while the total distance, including harbor channels, is 49.35 miles.

The total length of curves is 19.17 miles, leaving 30.18 miles of tangents or straight portions.

The width adopted for the canal will be sufficient to permit steamers to maintain a speed of six to eight knots per hour, and to allow two ordinary merchant steamers to pass each other on the line of the canal without stopping.

At Gamboa there is to be located a dam, either of masonry or of earth and masonry combined, for the control of the Chagres, and at Corozal, sluices by which, during half the tide period when the level in the Pacific is lower than that in the Atlantic, water can be discharged from the canal into Panama Bay.

The accompanying table gives the total excavation as very carefully computed from the data supplied by the Isthmian Canal Commission, supplemented by data collected at the instance of the Board.

(B) HARBORS.

THE HARBOR OF COLON.—A first-class natural harbor is not found at either terminal of the canal, but good harbor accommodations can be created without unusual difficulty or extraordinary expense.

Limon Bay, on the easterly side of which is the city of Colon, must be the Caribbean terminal of the canal. It is shallow, freely open to the sea from the north, and but little less exposed to the northeast and northwest. The depth of water at the entrance to the bay in its central portion is from 30 to 38 ft. opposite the water front of Colon. The southern half of the bay is so shallow as to be of no value for harbor purposes. The depth of water varies from 28 ft. opposite Cristobal Point, and gradually shoals to the gently sloping sandy beach at the extreme southerly end.

After much consideration of all the conditions bearing upon the construction of a safe and commodious harbor, the Board provisionally adopted two converging breakwaters, one extending from the beach to the easterly of the light-house in a northwesterly direction one mile, to a point where the low-water depth is at least 40 ft. and a short distance westerly of a small reef; the other starting from a point about 3,750 ft. west of Manzanillo light, running also one mile to a point where the depth at mean low water is at least 40 ft., so placed as to afford an entrance between the extremities of these breakwaters, 1,000 ft. in width, the southerly extremity of the latter breakwater to be connected with Great Reef, off Mindi Point, by a breakwater or stone dike 2½ miles in length. The nearest point of this breakwater to Cristobal Point would also be about 3,750 ft. These breakwaters, therefore, would inclose a harbor area nearly 9,000 ft. long from the entrance and nearly 4,000 ft. wide for a distance of at least eight-tenths of a mile, within which the depth at low water would vary from 30 to 35 ft. Within the protected harbor a dredged entrance channel 500 ft. wide on the bottom and 40 ft. deep at low water would lead straight from the entrance between jetties to the canal entrance near the mouth of the Mindi.

THE HARBOR OF ANCON.—The harbor conditions at the Pacific terminus are radically different from those found at the Caribbean end, in that no storms ever occur of sufficient magnitude to disturb vessels anchored in the roadstead northerly of the islands of Perico and Naos, the usual anchorage, which is three miles by the present dredged channel to the entrance of the canal at La Boca.

The French location extending from Miraflores to the anchorage ground in deep water requires much more curvature than is desirable for a canal entrance, and the Board believes that a straight entrance possesses sufficient additional advantages over the old one to justify substantial increase in expenditure to obtain it. A new alinement, therefore, for the Pacific end of the canal and the dredged channel has been adopted, extending from a point between Corozal and Miraflores on a straight course to the new site of the tidal lock between Sosa and Ancon hills, thence with a slight change in direction near the lock directly to deep water off the island of Flamenco. Rock outcrops between Ancon and Sosa hills and that vicinity afford a perfectly satisfactory foundation for this structure.

The question of the necessity of a tidal lock at the Panama end of the canal has been raised by engineers of repute, but the limited time available to the Board has not permitted the full consideration of this question which is desirable. It is probable that in the absence of a tidal lock the tidal currents during extreme oscillations would reach five miles per hour. While it might be possible to devise facilities which would permit ships of large size to enter or leave the canal during the existence of such currents, the Board has considered it advisable to contemplate and estimate for twin tidal locks located near Sosa Hill, even though the period during which they would be needed would probably be confined to a part of each spring tide.

The highest recently recorded range of spring tides which the Board has seen (September, 1905) was 19 ft. 9 ins. between extreme low and extreme high water, while from 1882 to 1887 the highest amplitude reported was 20.93 ft. With such tides for a brief period at dead low water there would be a differential head of about 10 ft.—that is to say, the water in the canal would be 10 ft. above that in the bay, while at extreme high water for a correspondingly short period the level of the water in the bay would be 10 ft. higher than that in the canal.

At the period of mean tide there would be no difference of level between the bay and the canal, so that during that period of the tide all the gates of the tidal lock could be open, leaving an unobstructed passage for vessels until the approach of the flood tide rendered it necessary for the gates to be closed until slack water would again be reached, and so on for each succeeding spring tide. During neap tides the range is so small that it will not be found necessary to bring the gates of the lock into use. Consequently, throughout the neap period of each tidal cycle a continuously open and unobstructed passage for traffic will be provided through the tidal locks.

(C) CROSS SECTIONS OF THE CANAL PRISM.*

In the judgment of the Board the depth of water in the canal prism and in both of the approach channels of the terminal harbors should not be less than 40 ft., except in the case of the channel in the bay of Panama, where at intervals that depth would not be found during short periods at extremely low spring tides.

The standard bottom width in firm earth, including the dredged portions in soft material between the shore line of Limon Bay and Bohio, was fixed at 150 ft., the side slopes in the same material being taken at 1 vertical on 2 horizontal.

In rock the bottom width was taken at 200 ft. with side slopes in the channel of 10 vertical on 1 horizontal, i. e., practically vertical. The side slopes above water, as well as below, in firm earth between Bohio and Obispo and south of Paraiso were taken at the inclination of 2 vertical on 3 horizontal.

In the great summit cut the surface material overlying the rock for a considerable distance in the vicinity of Culebra Hill is clay, which, like all clay, slips easily when wet. When, however, this clay is drained, or otherwise protected from becoming saturated, it stands with satisfactory firmness and gives no trouble. Throughout these combined rock and earth slopes the rock is given a face slope in the estimates of 10 vertical on 1 horizontal and the clay or other material above it 1 vertical on 2 horizontal. In the great Culebra cut, which really means the summit divide from Obispo to Pedro Miguel, a distance of 7¼ miles, a special form of section has been taken, although it includes the same elements of slope adopted for other portions of the cuts taken out in the dry. The same rock section for the prism of 200 ft. bottom width and with side slopes of 10 vertical on 1 horizontal is carried up to an elevation of 10 ft. above mean tide, at which elevation there is provided a horizontal berm 50 ft. in width on each side of the canal prism. From the exterior limits of these berms benches are assumed for the purpose of estimate, each 30 ft. high, with a face slope of 4 vertical on 1 horizontal, the width of the bench at top being 12½ ft. These benches are carried to the upper limit of the rock portion of the cut. This makes the average or mean slope of the rock 3 vertical on 2 horizontal. The clay or other soft material overlying the rock is given the same slope of 1 vertical on 2 horizontal already described.

It is believed by the Board that the estimated volume based upon these side slopes is ample. It is probable that large portions of this summit cut, composed of harder rock than the indurated clay which forms the material classified as soft rock, will permit of faces having a slope of four vertical on one horizontal to be taken out much higher than 30 ft. It is further be-

*See Fig. for diagram.

ESTIMATE OF EXCAVATION OF A SEA-LEVEL CANAL 40 FEET DEEP. [December 22, 1905.]

Stations.	Classification.	Cubic yards.		Unit price.	Amount.	
41-ft. contour to shore line of Limon Bay, 0 to mile 3.92.	Earth	2,781,698		$0.15	$417,250.00	
	Indurated clay	5,566		.70	3,896.20	
	Coral	135,500		1.50	203,250.00	
			2,922,734			$624,396.20
Shore line to Mindi, mile 3.92 to mile 5.49	Earth	7,695,885		.25	1,923,971.25	
	Indurated clay	2,351,588		.70	1,646,111.60	
			10,047,473			3,570,082.85
Mindi to Bohio, mile 5.49 to mile 17.22	Earth	21,730,453		.25	5,432,663.25	
	Rock above sea level	628,088		1.00	628,088.00	
	Rock below sea level	2,198,643		2.50	5,497,107.50	
			24,557,584			11,557,858.75
Bohio to Obispo, mile 17.22 to mile 30.96	Earth	48,787,149		.40	19,514,859.60	
	Rock above sea level	4,490,926		1.15	5,164,564.90	
	Rock below sea level	7,396,362		2.50	18,491,905.00	
			60,674,437			43,171,329.50
Obispo to Pedro Miguel, mile 30.96 to mile 39.04	All material above + 10.	93,697,408		.80	74,957,926.40	
	All material below + 10.	16,194,302		1.25	20,242,877.50	
			109,891,710			95,200,803.90
Pedro Miguel to Miraflores, mile 39.04 to mile 40.77	Earth above sea level	2,136,125		.40	854,450.00	
	Earth below sea level	300,000		.25	75,000.00	
	Rock above sea level	518,881		1.15	596,713.15	
	Rock below sea level	2,474,138		2.50	6,185,345.00	
			5,429,144			7,711,508.15
Miraflores to south end of Sosa lock, mile 40.77 to mile 45.37	Earth	6,103,828		.40	2,444,731.20	
	Rock nearly all below sea level	5,223,700		2.50	12,659,250.00	
			11,330,528			15,103,981.10
South end Sosa lock to 45-ft contour in Pacific, mile 45.37 to mile 49.35	Earth	3,508,945		.15	536,341.75	
	Rock	2,663,922		2.50	5,659,805.00	
			6,172,867			6,196,146.75
	Total		231,026,477			$183,136,107.30

Contours refer to mean sea level.

lieved that there will be little sliding of these benches, assumed in the computations of quantities, so that the volume taken out of the great summit cut is much more likely to be less than estimated than in excess of it, especially as a contingent margin has been added to all items of cost.

The materials classified as soft and hard rock have been exposed with surfaces fully as steep as 4 vertical on 1 horizontal ever since the old company ceased work in 1889, a period of 16 years. Furthermore, these slopes and others equally steep produced by the excavation made by the new French company have been under the personal observation of two members of the Board throughout the past six years, and under the daily observation of another member for over a year. During this time the effects of weathering have been small, soft rock as well as the hard having stood without sensible slipping or other deterioration. In fact, it is the result of extended experience with these steep faces both in Central America and on the Isthmus that the steeper the faces stand without crushing at their lower portions the less weathering and wash from the tropical rains will occur. It is therefore highly desirable to finish these slopes in as high benches and with face slopes as steep as practicable.

Very few slips of rock have occurred in the deepest portions of the Culebra cut since it was first opened. They are small and have been of such rare occurrence as not to affect the correctness of the preceding observations.

(D) ESTIMATE OF COST

The unit prices to be applied to the various items of work entering the completion of a sea-level canal have been formulated by the Board after most careful deliberation upon all the conditions affecting the actual prosecution of the work, including climatic effects, inefficiency of available labor, the distance of centers of supplies, the present condition of the various incomplete excavations, the general experience of the Isthmian Canal Commission since its creation, and other influences peculiar to the circumstances which will surround the execution of work in the field to its completion. It has been the intention of the Board to make these prices liberal, so as to remove as far as possible any probability of the ultimate cost of the work being greater than that estimated, and it is believed that they are sufficiently liberal to accomplish that purpose.

It will be observed that they pertain to methods and material which have been well tried in engineering construction and do not rest upon anything of an experimental character, as it is the judgment of the Board that nothing should be included in the proposed plan other than that which has been justified by engineering experience with work as nearly similar to that contemplated in this project as possible.

The Board has taken account of and given due weight to the fact that vast improvements in mechanical excavating devices have, in the past few years, been made and their effectiveness demonstrated. The Board also believes that other improvements specially applicable at Panama will be developed and used as the work progresses, as was the case during the making of the Suez and the Chicago Drainage Canals, and that these improvements will result in large economies and show that the unit prices are much too large; but in fixing these units account has been taken of nothing which has not been tested and justified in actual practice.

Applying the unit prices adopted to the quantities—a tabulation of the main items with a grouping of the smaller items—the following estimate of cost results:

Jetties in Limon Bay	$5,000,000
Excavation and dredging in earth, rock, etc., throughout the canal	183,136,000
Completion of river diversions, formation of dams across tributary streams, regulation of rivers which flow into the canal, etc.	3,500,000
Dam across Chagres Valley at Gamboa, with flood sluices, etc.	6,000,000
Spillway, with flood sluices, near La Boca	920,000
Twin tidal locks in the Ancon-Sosa saddle	6,000,000
Leading jetties above and below locks	795,000
Relaying track of Panama Railroad	500,000
	$205,851,000
20% for contingencies, administration and engineering	41,170,200
Total	$247,021,200

The Board is confident that the Panama Canal can be constructed and completed under the plans set forth and recommended in this report within the preceding total sum of $247,021,200.

There are certain items of cost, such as construction of military defenses, naval stations, government of the Canal Zone, sanitation, light-houses, buoying, lighting, and the provision of tugs, lighters, derricks, dredges, scows, etc., which have not been included. They are common to any type of canal. It was not understood to be the desire of the President that the Board should take into account anything that did not relate to the engineering features of the canal construction, but there is no doubt, in the opinion of the Board, that the expense of maintenance of a sea-level canal will be very much less than for a canal requiring lift locks.

Assuming that the total cost of the Panama Canal, including construction, payments to the French company for the property and franchise, to the Panama Republic for the rights conveyed, the cost of the Zone government until the canal is open, and other collateral costs, the total possibly reaching $333,000,000, the interest charge on this sum as 3% would reach $10,000,000. That such an investment would be a safe one from a commercial standpoint is indicated by the fact that the interest and dividends paid to the owners of the Suez Canal last year reached the total of $17,000,000, after paying all expenses of maintenance and operation, also the cost of the extensive enlargements and deepenings which are continually in progress.

(E) ESTIMATE OF TIME.

As affecting the question of time for completion, and in marked degree that of cost also, there are two features of the sea-level plan which are of great moment: One is the excavation of the channel through the great divide, amounting to about 110,000,000 cu. yds in a length of about seven miles, and the other the construction of the tidal lock near Ancon-Sosa, having a usable length of 1,000 ft. and width of 100 ft., with a maximum lift above mean sea level of 10 ft., this structure requiring over 600,000 cu. yds. of concrete and other masonry. These two features have received an extended and careful study.

Inasmuch as hard rock outcrops in the immediate vicinity of the tidal lock site near Sosa Hill the amount of excavation required to secure a suitable foundation is not large and it can be expeditiously completed. The most serious part of this particular problem is to secure and assemble at the site the requisite cement, sand, gravel, or broken and other stone, and the plant required to mix and put in place the great mass of concrete and granite for the masonry portion of the lock. The gates as planned would be of steel, and each leaf would weigh about 275 tons. Their construction, shipment to the Isthmus, and erection in the locks would probably require a period of nearly two years. The Board has estimated that the time required for placement of the concrete and stone work would be four years after the excavation had been completed. It is therefore reasonable to estimate that the entire twin-lock construction, including excavation, concreting, erecting gates, and installing machinery, will require a period of not more than eight years.

It may be suggested that the Gamboa dam, built to the height of 180 ft. above the rock in the deepest place, is also a great controlling factor as respects time, but the Board does not indorse such an opinion. If the dam be entirely of masonry, and allowing amply for interruptions by freshets or floods, the structure can easily be completed in less time than the tidal locks.

The excavation of 110,000,000 cu. yds. probably can not be completed in the seven miles of summit cutting within the period of eight years which are estimated to be requisite for the construction of the tidal locks. The excavation at the summit may therefore be considered as the controlling element in the time required to build a sea-level canal.

The time required to remove this great mass of material, by far the greater part being soft and hard rock, will depend greatly upon the efficiency of the method of operation and the organization of force and plant, all of which must be ultimately the result of most careful consideration of all the elements, including those of climate and character of labor available. It is clear that for the best results the greatest possible amount of work must be done by mechanical appliances and the least possible by manual labor. It is equally clear that the methods of conducting the work, including the control of the plant and force, must be such as will be subject to a minimum of climatic interference and effects of rainfall in the rainy seasons. All parts of the cut must be completely drained, so that the effects of rainfall and springs on the material to be moved may be reduced to the lowest limit.

In considering this part of the Board's work it has taken full evidence regarding this great excavation from not only the present and former chief engineers of the Isthmian Canal Commission, but also from the division and resident engineers who have had the direct charge of the work. The records and plans of the French engineers and committees have been diligently studied. It appears safe to estimate from this evidence that from 80 to 100 steam shovels of the most effective type now in use on the Isthmus can be efficiently employed continually on this work after complete organization. It will require from 2 to 2½ years to install and put in operation this excavating plant. The independent studies by the Board of the arrangement of railroad tracks and of complete systems of attack at both ends of this summit cut completely confirm the conservatism of the evidence given before it. It is as clearly demonstrable as any estimate of rate of progress and time for the completion of any great engineering work can be that after the full installation of plant not less than 100 steam shovels may be continuously engaged between Obispo and Pedro Miguel until the amount of work remaining to be done becomes too small to afford space for the operation of the whole plant.

The Board recognizes that the removal of the material in the summit cut is in reality a problem of transportation. It is a comparatively simple matter to excavate the material within a much shorter time than that allowed for the work, even on the supposition that all of it except the clay near the surface must be shattered by preliminary blasting. The whole difficulty attending this part of the construction of the canal is attached to the removal of the material from the shovels or other excavators to the spoil banks. This problem of transportation is in reality the substance of the problem of building the transisthmian canal and, in treating this part of the project, the Board realizes and has considered the large amount of railroad track and the extensive transportation organization required for the disposition of the waste material. It is probable, as has been estimated, that not less than three miles of standard track will be required for each shovel employed, making a total of 300 miles of trackage for 100 shovels.

If it be assumed that 100 shovels are available for continuous work, there being a sufficient surplus above that number undergoing repairs whenever necessary to maintain the working complement, it can be demonstrated that as much as 20,000,000 cubic yards of material classed as rock may be annually removed from the summit cut. This estimate is based upon an average number of working days of not more than 20 per month throughout the year, which is an underestimate on the basis of the experience of the French companies and of that which has accrued since American occupation began, in May, 1904. In this estimate the capacity of one shovel is taken as materially less than would be justified by the actual operations of steam shovels in the Culebra cut during the past year, both in wet and dry seasons. Furthermore, it has been supposed that the working day is to be but eight hours long and that one shift only of laborers would be employed per day, whereas it is perfectly feasible to work two shifts in twenty-four hours during the greater part of the year and possibly during the entire year. Using these estimates for the period of what may be assumed to be the maximum annual output in the Culebra cut, and allowing at least two and a half years to attain this maximum rate at the beginning of the work and a period of not less than three years for a decreasing output in the more contracted space in the lower portions of the cut during the closing period of operations, it is found that the entire quantity of 110,000,000 cu. yds. of material in the divide can be removed within ten years. (For time curve illustrating practicable excavation of Culebra cut, see Fig. 8.)

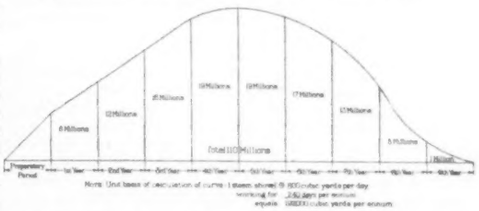


Fig. 8. Graphical Illustration of Practicable Yearly Excavation Which Would Complete Culebra Cut for a Sea-Level Canal in Less Than Ten Years.

Although the preceding estimate of time has been based upon ample allowances for the effect of the rainy seasons, for the low grade of labor available on the Isthmus, and for climatic conditions in general, the Board has added about 25% to it for other contingent causes of delay, either similar to those already provided for or of any other character. It is therefore the judgment of the Board that a ship canal on the sea-level plan outlined in this report can be completed within a period of time not exceeding twelve or thirteen years.

(F) IMPORTANT CONSIDERATIONS.

It is essential that the Panama Canal shall present not merely a means of interoceanic navigation—it may be said that any type of canal would enable vessels to pass from ocean to ocean—but a means of safe and uninterrupted navigation, on which no special hazards will be encountered by and no vexatious delays will be occasioned to the vessels which will traverse it.

The Board is of opinion that this consideration should be of determinative force in respect to the type of canal to be adopted, and that it should lead to rejection of all proposed plans in which lift locks, whether few or many, form the principal or dominating features, and consequently to the acceptance of the sea-level plan as the only one giving reasonable assurance of safe and uninterrupted navigation.

It is not suggested that a maritime canal with locks forming the essential feature is an inherently unsafe system of navigation, for experience has not only demonstrated the contrary, but also that the matter is one of degree. A navigation with locks of small size capable of passing the ordinary commercial steamers may be made reasonably safe, while a maritime waterway with locks of the dimensions which the Board has considered to be

necessary in order to meet the requirements of the Spooner Act might be and is thought to be so unsafe for the passage of the great seagoing vessels contemplated by that act as to be altogether beyond the limit of prudent design for safe operation and administrative efficiency.

In the course of the proceedings of the Board it transpired that during the last nine years three accidents arising from collisions between steamers in transit and the lock gates, and resulting in each case in dangerous damage to these gates, occurred in the St. Marys Falls Canal; and also that three accidents arising from the same cause and having the same result occurred in the Manchester Ship Canal in England.

Several of these accidents were so serious that disastrous consequences were escaped by a narrow margin only. It is practically certain that if the locks upon which these accidents took place had been of the dimensions and had controlled the great differences of level contemplated for the locks of the Panama Canal, not merely serious accidents but disasters would have followed in perhaps all these cases, throwing the whole canal out of operation for a period which cannot be estimated, and also wrecking the vessels in the path of the resulting flood, while the cost required to repair the damages is not within the limits of reasonable computation.

The three accidents at St. Marys Falls Canal occurred within a period of nine years, where there is only one lockage of about 20 ft. If six locks should be adopted in a plan for the Panama Canal, each having a lift of 30 ft. or more, as has been proposed in several projects, it would not be unreasonable, with an equal number of vessels, to look for six times the number of accidents in the same period of time, which would be at the rate of two per year. If groups of locks should be arranged in flights, as has also been proposed in some projects, the imminence of disastrous accidents would be greatly enhanced, as would be the amount of damage to the structures and to the vessels involved. Indeed, it is highly probable that the grave disaster of a great ocean steamship breaking through the gates of the upper lock and plunging down through those below might be realized.

As there is no maritime canal in the United States or about its borders it is natural to regard the navigation of the St. Marys Falls Canal as exhibiting conditions practically parallel to those which would exist in the Panama Canal, but inferences drawn upon such a basis may be greatly misleading. The lock in that canal has been so successfully operated and its administration has exhibited such gratifying results that there is danger of forgetting that it is located in an environment of a highly special character. It is now a marked feature of the navigation route of the Great Lakes. The masters of the vessels passing this canal and lock are therefore familiar not only with every detail of the short canal in which the lock is located and of the lock itself, but also of every circumstance of its operation. They pass to and fro with their ships every two or three weeks during the period of navigation, so that the vessels which the lock serves are almost fixed features of a daily routine from which there is little or no variation. Entrance to and exit from the lock becomes by constant familiarity a routine performance in which constant repetition leads to a degree of skill and safetly which can never be attained in a maritime waterway like that of the Panama Canal, serving the commerce of the world, carried in vessels whose masters would come in contact with the physical conditions surrounding the locks and the regulations governing their operation at rare intervals only, and whose crews would be absolutely strange to every feature of this canal service. Under such circumstances any variation from the simplest and plainest conditions of navigation would necessarily be a source of grave danger and likely to lead to serious accident.

It is true that a sea-level canal or any restricted waterway may be closed by accident, as by a vessel stranding or sinking. Such an obstruction would be temporary only, as it could be removed in a few days, even if the wreck had to be blown up, as recently occurred in the Suez Canal, an incident mentioned elsewhere in this report. Such an accident is not to be compared with those greater and more far-reaching, resulting in the destruction of the lock gates, the drawing off of the water from the summit level, and the possible serious damage to the canal prism.

It may be argued that the objections to which we have referred as existing to the employment of lift locks apply also to the sea-level plan in which the construction of tidal locks at or near the Pacific terminus is a feature. In reply it may be conceded that the argument is at first sight a fair one and that due weight should be given to it; but while it is clear in any case that one obstruction in the course of a maritime highway would be preferable to six or eight, the difference between the functions of any lift lock in the lock-canal proposal and those of the tidal locks in the sea-level plan should be clear to any impartial critic.

The tidal lock is for regulating purposes only, and the reason for its introduction is due to the natural circumstances which exist, there being practically no tidal range in the bay of Limon, at the Atlantic end of the canal, while in the bay of Panama, at the Pacific terminus, the range at high spring tides is more than 20 ft.

Much has been said in the projects submitted to the Board about the advantages of lake navigation in the great reservoirs or lakes which it has been proposed to create by dams across the Chagres on the one side of the Isthmus and across the estuary of the Rio Grande on the other. Extended experience in the navigation of maritime canals on the continent of Europe and in Great Britain has shown that this advantage is largely imaginary, for it has been found in such canals, with prisms of much less dimensions than those recommended for this route, that steamers of the largest size which they can accommodate may steam through them at speeds of about six miles per hour without any real difficulty or danger. Such is the case in the Suez Canal and the Manchester Ship Canal. As a matter of fact, throughout the greater part of the Panama Canal traversing the proposed lakes the actual channels would have sub-

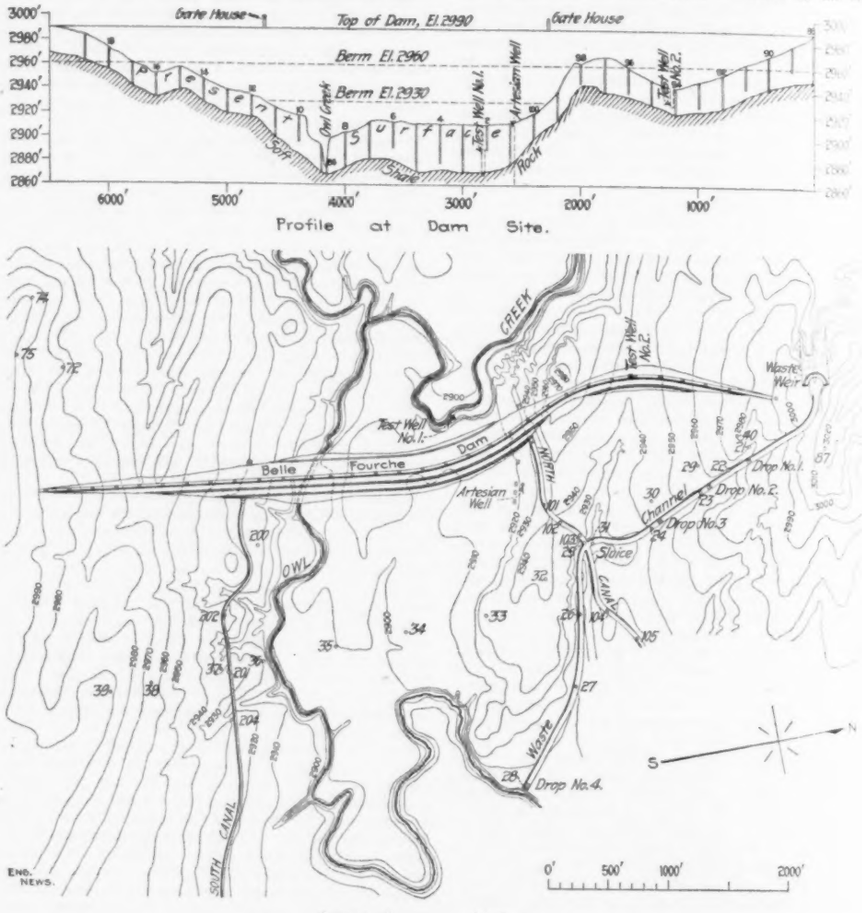


FIG. 1. PLAN AND PROFILE OF EARTH DAM, BELLE FOURCHE IRRIGATION PROJECT, U. S. RECLAMATION SERVICE.

merged banks, necessitating buoys, and within which the speed of vessels would not greatly exceed that possible in the sea-level canal.

The maintenance and operation of locks is also costly. If of such great dimensions as those considered necessary by the Board under the Spooner Act, they require the installation, maintenance, and operation of an extensive power plant for the working of the gates. It is not easy to estimate what the annual cost of maintenance, including renewals and operation, of these would be, but, using the estimates of the Isthmian Canal Commission of 1899-1901, it is probable that the annual cost of operation of the six locks contemplated in the projects brought before the Board would be about $525,000. This annual charge capitalized at 3% would make a sum of $17,500,000 to be added to the cost of the lock canal. The corresponding item in the sea-level plan would be the capitalized annual cost of operating the tidal locks near Panama.

It has already been stated as the opinion of the Board that the time required for the construction of the Panama Canal with a summit level at 60 ft. above mean sea level will at best be only two years less than required for the construction of the sea-level canal. But as affecting this question of time, it should be observed that accidents during construction leading to an extension of the time required to complete the canal would be more likely to occur in the more numerous structures involved in the building of the lock canal than in the [illegible] for the sea-level canal. It has further been shown [illegible] the difference in cost between the two plans will not exceed about $71,000,000 in favor of the former, which [illegible] be reduced by the capitalized cost of the maintenance and operation of locks and by the cost of the [illegible] lands, as before stated.

It is seen, therefore, that the lock design has [illegible] considerable advantage either in time of realization or [illegible] ultimate cost over the one recommended by the Board for adoption by the United States Government, which possesses all the advantages of practically indefinite capacity for traffic, besides a degree of safety and uninterrupted operation which cannot be approached by any lock plan.

It is the belief of the Board that the essential and the indispensable features of a convenient and safe ship canal at the American Isthmus are now known, that such a canal can be constructed in twelve or thirteen years' time; that the cost will be less than $250,000,000, that it will endure for all time.

For all these reasons the Board recommends that the sea-level plan be adopted for the Panama Canal.

Mr. Quellennec's indorsement of this report is to be considered in connection with his statements qualifying his vote as recorded in the minutes of the nineteenth and twenty-fifth meetings.

Respectfully submitted,

Geo. W. Davis, Wm. Barclay Parsons, Wm. H. Burr, Wm. Henry Hunter, Ad. Guérard, Eugen Tincauzer, J. W. Welcker, E. Quellennec.

THE BELLE FOURCHE IRRIGATION WORKS, SOUTH DAKOTA.

By Walter W. Patch,* Assoc. M. Am. Soc. C. E.

Among the many irrigation projects now being developed by the U. S. Reclamation Service, one of the most attractive is the one near Belle Fourche, S. Dak. The main features of this project are a concrete diverting dam, a large canal, a long, high earth dam, providing an immense storage reservoir; a main and lateral canal

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system covering 90,000 acres, and a new townsite.

The area to be irrigated is located near the western border of the State, in Lat. 45°, and at an elevation of 3,000 ft. above sea level. The almost entire absence of severe heat makes the summer weather delightful; and although the minimum winter temperature is —35 to 40° F., the winters are relatively short, and in the prevailing dry, clear atmosphere such extremes of cold are not comparable with the same temperatures in a moister climate.

The normal rainfall at Belle Fourche is about 15 ins., and in some years is large enough to permit the growth of excellent crops of hay and grain. The soil is generally heavy and very fertile, and where under irrigation, as is some of the adjacent land to the south, it is highly productive for hardy fruits, hay, grain, alfalfa, etc. With the advent of irrigation, insuring the successful raising of crops every year, 90,000 acres of land, now valuable only for cattle grazing, will afford homesteads for the founding of a large and prosperous agricultural community.

Across the Belle Fourche River, 1½ miles from the town of Belle Fourche, a concrete diverting dam is being constructed, which, during the larger part of the year, will turn the entire run-off from about 4,300 sq. miles into a canal 6½ miles long, capable of carrying 1,635 cu. ft. per sec. Flood flows, up to 20,000 sec.-ft., can pass over the crest of the diverting dam, and will be kept out of the canal by massive iron sluice gates installed at the headworks.

The canal skirts the high ground on the northerly side of the river valley. It has a grade of 1 in 5,000, compared with a fall of about 9 ft. to the mile, measured along the axis of the valley. Six miles below the diverting dam the canal makes an abrupt turn, pierces the divide in an open cut of 40 ft., maximum depth, and then discharges into an arm of the storage reservoir.

Water delivered by the main canal will be impounded by an immense earth dam, now being built across Owl Creek, a tributary of Belle Fourche River. The reservoir thus formed will have a high water area of 8,000 acres, a total capacity of 215,000 acre-ft., or 70,000,000,000 gallons, of which 200,000 acre-feet is above the elevation of the outlet conduits through the dam.

In addition to the rainfall, a total depth of 2 ft. of water applied during the growing season to the 90,000 acres of irrigable land is estimated as sufficient to satisfy the requirements of plant growth. The surplus storage is believed to be ample to make good evaporation, seepage and losses attending distribution. The drainage area of Owl Creek, above the dam site, is 170 sq. miles; and, while there is no water running in the creek for the major part of the year, the flow during freshets is large in volume for a short time, and would yield a small increment to the storage.

One of the most interesting features of the project is the earth reservoir dam, the construction of which is just commencing, and which will be in progress during the next four years. It will be 6,500 ft. long, 115 ft. in maximum height, and will contain about 1,600,000 cu. yds. of materials. Judged by its great mass and the enormous storage in the reservoir, this dam will be one of the most notable structures of its kind.

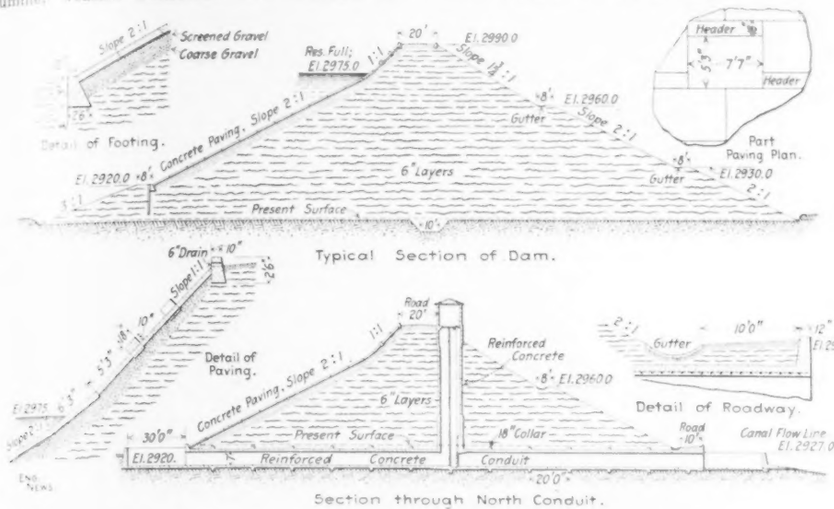


FIG. 2. CROSS-SECTIONS AND DETAILS OF BELLE FOURCHE DAM.

The soil at the dam site and in the country adjacent thereto is a heavy adobe clay, weighing when dry from 105 to 110 lbs. per cu. ft., and is known locally as "gumbo." Underlying the clay, at depths from 10 to 40 ft., is the native shale, relatively soft and disintegrated at first, but gradually growing harder, until a hard slate is found at a depth of several hundred feet. There is no sand or gravel within this territory, except for occasional small pockets of gravel here and there in the creek channel. And as the latter will be excavated to shale and backfilled with impervious materials where it crosses the dam site, it is difficult to believe that seepage past the dam will occur in any appreciable amount.

As indicated in part by the plan and profile, Fig. 1, a large number of earth auger borings, as well as numerous open test wells, have been made to determine beyond a doubt the general uniformity of all the materials, both beneath the dam and on the site of possible borrow areas. The clay requires to be picked before it can be shoveled, and as excavated contains many hard lumps which can be broken up only by very thorough rolling or by heavy tamping, in thin layers.

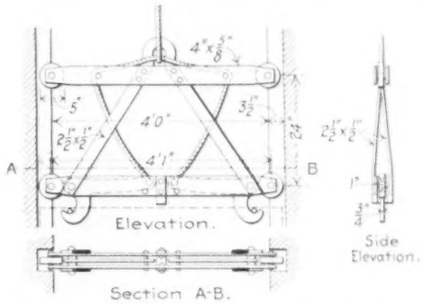
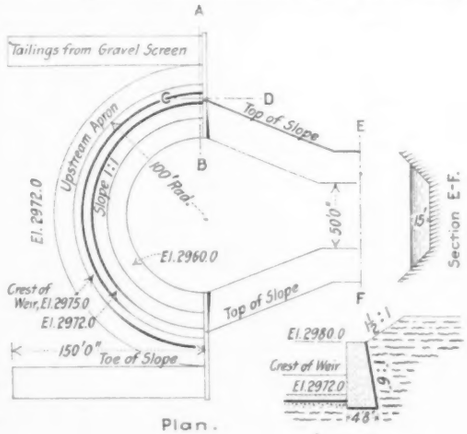


Fig. 3. Details of Stop-Plank Lifter for Gate Chambers, Belle Fourche Dam.

It will be noticed that the center line of the dam is not straight in plan, but comprises three tangents connected by curves of 4° and 3°, respectively. This curvature was introduced as a matter of economy, for the volume of the dam as located is computed to be about 10% less than could be obtained from any single tangent alinement.

Excepting near the top, the section of the dam, as shown by Fig. 2, has 2 to 1 slopes on each face, with berms at 30-ft. vertical intervals on the downstream slope, and a berm on the upstream slope about 10 ft. below low water, the latter serving to secure a firm foundation for the slope paving. Below the upstream berm the slope of the embankment will be 3 to 1, with such temporary protection against wave action as may be necessary during the short period when the reservoir is filling to low water elevation. Spoil banks of waste materials will also be distributed along this slope as an additional protection against erosion. Above high water level the upstream slope is 1 to 1, both in the interests of economy and to check more quickly the rush of waves.

Berms on the down-stream slope will be pro-



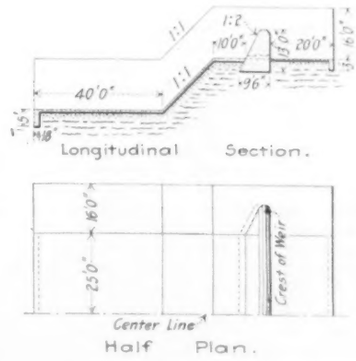


Fig. 5. Drop in Waste Channel, Belle Fourche Dam, South Dakota.

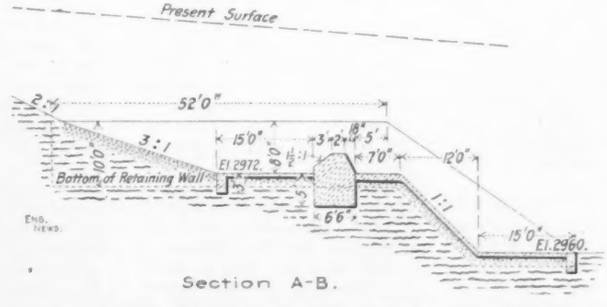


Fig. 4. Details of Semi-Circular Waste Weir, Belle Fourche Dam, South Dakota.

vided with concrete gutters designed to discharge at the rate of 1 in. of rainfall collected in ten minutes from the tributary area. The face of the embankment will be dressed with 12 ins. of loam, which is to be fertilized, seeded and sprinkled until a healthy sod is formed. Between the upper berm and the top of the dam the slope will be steepened to 1¾ to 1 in order to save material. While observation fails to show natural slopes in this vicinity which retain a sod on slopes steeper than 2 to 1, it is expected that with care a better and stronger sod can be obtained on the embankment; but should erosion commence on the steeper slope, repairs can be made with materials delivered from the roadway along the crest of the dam.

The prevailing winds for the greater part of the year blow down the valley towards the dam. As the reservoir when full will be eight miles long and more than 60 ft. in depth for a considerable distance, wave action is expected to be very violent; and the form of slope paving to be adopted thus becomes one of the most important features of the problem.

The material for the embankment, when exposed to water, swells slightly, softens on the surface, and becomes exceedingly slippery; but when covered by a layer of gravel the softening of the surface is very largely prevented. It was decided, therefore, in any case to protect the embankment slope by a layer of gravel, upon which the paving could be bedded. The nearest stone quarry is in the Black Hills country, 20 miles by rail from Belle Fourche. This stone is a medium grade of sandstone, not very desirable for use in paving on such an exposed location; and on account of a twelve-mile wagon haul from Belle Fourche to the dam site it would be fully as expensive as concrete.

Gravel of excellent quality and in very large quantity is found in the Belle Fourche River valley, about six miles from the dam site. It will be used both in making concrete and as a cushion between concrete and earth embankment. Studies and estimates were made for three forms of concrete paving:

(1) Reinforced concrete in large thin slabs.

(2) Plain concrete blocks made in place as the embankment progresses.

(3) Concrete blocks of about 3,000 lbs. weight, made at any convenient point, and, after seasoning for not less than three months, to be placed by traveling derricks.

The third scheme figures somewhat the cheapest, and for several reasons is the most convenient. The specifications provide that, after the second season, the reservoir may be partially filled, and that the amount in storage may be increased as the embankment grows in height. In fulfilling this condition the paving must be laid a course at a time, keeping pace with the earthwork. This can be done very readily by taking blocks from a storage yard, whereas under either scheme (1) or (2) the concrete force could work but a few days at a time, and then would have to be laid off or transferred to other work for a considerable period.

Blocks can be brought in by night on the track used by dirt trains, and stacked within reach of the derrick used in laying them. For concrete made on the slope a special supply track would be required, or else materials would have to be transported long distances by wagon haul.

With a concrete force well organized and working continuously, a high degree of efficiency can be maintained, with a corresponding excellence and uniformity in the concrete.

Another advantage possessed by blocks is that, in case of subsequent damage to a block, it can be replaced much easier than repairs could be made to a reinforced slab.

Blocks are to be bedded upon 12 ins. of screened gravel, which in turn rests upon a 12-in. layer of gravel not screened. They are to be laid in contact, in regular courses, and with face joints not exceeding ½-in. This arrangement provides for perfect drainage, while not permitting the sand to be washed out through the joints. It is believed, also, that the winter ice sheet several feet in thickness will not be able to get sufficient hold on the paving to displace it.

From high water line to the top of the dam the paving will be 2 ins. thinner than below, and will contain two courses of alternate headers and stretchers, the former projecting to serve as breakwaters. Low curbings will surmount the embankment on each side of a 20-ft. roadway; the curbing on the upstream side having frequent openings so that spray which may have reached the top can drain back into the reservoir.

Water will be drawn from the reservoir through two reinforced concrete conduits built in the natural ground beneath the dam; the northerly conduit ordinarily discharging 650 cu. ft. per sec. and the southerly conduit 290 sec. ft.

Fig. 3 shows the details of a stop-plank lifter for the gate chambers.

The first 1,500 ft. of the north canal will have a section of sufficient size to act as a sluice channel, discharging 1,360 sec.-ft. into the waste channel. This amount, together with the full capacity of the south canal, slightly exceeds the carrying capacity of the inlet channel, 1,650 sec. ft. Although the reservoir at low water will contain about 15,000 acre-feet, this storage is at too low an elevation for use in irrigation, and as the valley is too wide for a silt blow-off to be effective, no provision has been made to drain this portion of the reservoir.

A waste weir (see Figs. 1 and 4) will be located in excavation beyond the northerly end of the dam. The crest of the weir is to be 15 ft. below the top of the dam. It is to be semicircular in plan, 300 ft. long, and will discharge 3,000 cu. ft. per sec. when under slightly more than 2 ft. head. The waste channel has a width of 50 ft. at the bottom, side slopes of 1 to 1 and a fall of 100 ft. in one mile, but this fall is concentrated at a series of dams or drops (Fig. 5), so that the velocity through the earth channel will not exceed 3 ft. per sec.

For the waste weir to discharge at the rate mentioned would require that the inflow to the reservoir be sustained continuously at the rate of 3,000 sec.-ft. for from two to three days before the water surface would become high enough to make an equal discharge possible over the waste weir. Such a run-off from the drainage area of Owl Creek would be highly improbable, for although the maximum rate of discharge of the creek may reach or even exceed this figure, the discharge curve is very abrupt and continues near the maximum for but a few hours. If, through carelessness, the inlet canal is permitted to operate during a flood, a continued flow of 3,000 sec.-ft. may be experienced, but in this case the outlet conduits through the dam could be used to lower the reservoir water level.

The dam will be built as an homogeneous embankment, without any core wall. The materials underlying it, as well as those entering into its construction, are impermeable to a very high degree, and when built in 6-in. layers, watered and rolled as specified with steam rollers weighing not less than 200 lbs. per lin. in. of roller rim, will make a very dense embankment. The closely jointed block paving covering the entire water slope will effectually prevent the operations of burrowing animals, while the passage of water beneath the dam will be prevented by plowing the surface upon which the embankment is built and by making a center cut-off trench which is to be back-filled with selected materials deposited in layers and rolled by steam rollers. The contract price for the dam is $879,000, and four years is the time allowed for its completion.

The distribution system will comprise several hundred miles of canals, laterals and sub-laterals, which will be built so as to be available for use when the reservoir storage is sufficiently advanced to supply them. About 13 miles east of the dam and near the center of the irrigated area a tract of about 900 acres has been reserved as a townsite. This will be cut up into town lots, which will be sold at public auction, the proceeds of the sale being used for building streets, water-works, sewers and other public improvements for the benefit of the town.

In accordance with the provisions of the reclamation act, the construction cost of the project, which is estimated as about $30 per acre, will be assessed pro rata against [illegible] farm units on the irrigated area, and will [illegible] payable by the settler in ten annual payments, the first of which will follow the harvesting [illegible] first crop.

The engineering force on the Belle [illegible] project is organized in two divisions—N[illegible] including headworks and inlet canal, being in charge of Mr. H. E. Green, M. Am. Soc. C. [illegible] while the writer is engineer of division N[illegible] including the reservoir, dam and adjacent [illegible] Mr. R. F. Walter is District Engineer for South Dakota, and has general charge of the project, and Mr. F. H. Newell, M. Am. Soc. C. E., is Chief Engineer of the Reclamation Service.

RESULTS OF TESTS MADE TO DETERMINE THE STRENGTH OF CONCRETE WHEN CEMENT IS MIXED WITH SAND, CLAY AND LOAM IN VARYING PROPORTIONS.*

The cement was "Double Anchor" German brand, the sand standard quality; the clay was taken from the cutter of a dredge working in Galveston channel; the loam was heavy black soil from the mainland. Both loam and clay were thoroughly pulverized, free apparently, from all vegetable matter and sand, and sifted to remove lumps. All briquettes were made from one sample on the same day, under same conditions. The clay acted so unsatisfactorily during the working of the 25% batch that no more briquettes were made for this particular test, but the loam was continued to 40%.

Tensile Strength Test Completed Aug. 1, 1904.

	Old shipment.					
	7 Days			28 Days		
	No. 1 Lbs.	No. 2 Lbs.	No. 3 Lbs.	No. 1 Lbs.	No. 2 Lbs.	No. 3 Lbs.
Sand and cement, 3 to 1	170	166	190	240	240	260
	180	168	191	245	230	265
Sand with 5% loam	187	....	....	250	....	....
	183	....	....	245	....	....
Sand with 10% loam	....	165	....	....	241	....
	....	175	....	....	250	....
Sand with 15% loam	....	....	203	....	....	275
	....	....	210	....	....	275

Tensile Strength, Test Completed Sept. 7, 1904.

	New shipment.	
	7 Days. Lbs.	28 Days. Lbs.
Sand and cement, 3 to 1	210	316
	207	337
5% clay	220	356
	218	343
5% loam	208	367
	201	350
10% clay	210	321
	213	330
10% loam	200	369
	207	395
15% clay	200	296
	208	301
15% loam	202	365
	205	368
20% clay	184	262
	189	267
20% loam	220	370
	216	372
25% clay	172	240
	166	251
25% loam	221	373
	218	375
30% loam	220	361
	225	350
35% loam	205	300
	198	306
40% loam	198	290
	189	279

Tensile Strength, Test Completed Nov. 5, 1904, for 3-Month Breaks; Test Completed Feb. 5, 1905, for 6-Month Breaks.

	Breaks	
	3 Mos. Lbs.	6 Mos. Lbs.
Sand and cement, 3 to 1	350	339
	328	346
5% clay	341	340
	336	334
5% loam	309	316
	321	320
10% clay	329	327
	336	334
10% loam	320	330
	329	331
15% clay	270	225
	260	220
15% loam	321	319
	328	315
20% clay	250	200
	258	216
20% loam	250	230
	241	225
25% clay	236	175
	216	190
25% loam	239	222
	248	217
30% loam	258	210
	250	216
35% loam	239	220
	248	212
40% loam	240	198
	232	213

*Extract from report on Defenses of Galveston, Tex., by officer in charge, Capt. Edgar Jadwin, Corps of Engineers, to Chief of Engineers, printed in the Report of the Chief of Engineers for 1905.

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The long-expected report of the Board of Consulting Engineers for the Panama Canal was transmitted to Congress by the President on Monday. As already foreshadowed in the newspapers, the Commission was divided, eight members favoring a sea-level canal and five members favoring a lock canal embodying radical changes from any plan heretofore considered.

We give up large space in this issue to a summary of the report, followed by a lengthy abstract of the majority report favoring the sea-level canal, and the recommendations of the Canal Commission itself approving the 85-ft. lock level plan as recommended by the minority members. The minority report itself we postpone to our next issue.

We may take space here to note that the Canal Commission criticises the estimates by the majority of the board for a sea-level canal and present facts and figures tending to show that the sea-level canal planned by the majority of the board would cost as much as $272,000,000, or $25,000,000 more than the board estimated. The Commission also expresses grave doubt as to the estimate of twelve to thirteen years as the time necessary for a sea-level canal, and says it is to be feared that the time required would reach eighteen or twenty years.

The Commission expresses its unqualified approval of the lock canal recommended by the minority of the board, which "can be built in half the time and for little more than half the cost of the sea-level canal," and will be, it believes, a safer and better means of interoceanic navigation.

The lock canal project is approved also by Chief Engineer Stevens and by Secretary Taft and the President. Unless Congress should interfere, therefore, the lock canal will be constructed.

Combined sewage works and refuse destructors are common enough in Great Britain, but as yet they are so rare in the United States as to make noteworthy the installation at Marion, O., described at length elsewhere in this issue. It will be seen on referring to the article that the combined plant is remarkably compact, and also that the author calls attention to the resemblance between the sewage filters there and the "controlled filters" of Mr. Baldwin Latham, described and commented on editorially in our issue of Dec. 21, 1905.

There is a still earlier combined sewage and garbage works in Ohio (at Mansfield), designed by Snow & Barbour, of Boston, but we are informed that no provision is there made for burning sewage sludge, as is proposed at Marion. The nearness of the Marion septic tank and its preliminary screening chamber to the crematory is a notable feature of the combined works at that place.

Probably the earliest American instance of burning sewage sludge in a garbage crematory was afforded by Coney Island (then a part of the town of Gravesend) years before its consolidation with Brooklyn and later with New York. The sewage works (chemical precipitation) at Coney Island was one of the earliest municipal sewage disposal plants built in the United States, having been put in operation in 1887. In the following year a garbage crematory, also one of the earliest in the country, was built alongside the sewage works. In this journal for Oct. 20, 1892, a description of the sewage and garbage works appeared. It was then stated "that for the last few years the sludge had been burned in the crematory." The sludge, after having sawdust mixed with it, was shoveled into the buckets, and the latter moved to the furnace by means of an overhead tramway. The crematory was not operated in winter.

While it may often be convenient and economical to combine, at least on one site, sewage and refuse disposal works, it seems unlikely that many attempts will be made, or, if made, continued, to burn crude sewage sludge and its 90% and upwards of water. The rakings from sewage screens may be burned to advantage, and if no other means of sludge disposal are readily available it may be advantageous to press and burn sludge, where a crematory is at hand. In the early days of the chemical precipitation works of Worcester some experiments with sludge furnaces were made, but nothing came of them.

One of our correspondents interested in irrigation work in the Far West sends us a letter, in which he suggests that the estimates of the possible area that can be irrigated in the "Great American Desert" have been much too conservative. These estimates have been based on the total run-off in the rivers of the arid region, it being taken for granted that all that can be done by man is to store the surplus water of the flood season, so that the entire flow of the river may be used for irrigation. Knowing then the approximate quantity of water required per acre for satisfactory irrigation, it is easy to compute that the ultimate possibilities of irrigation involve the reclamation of not more than a sixth of the arid region.

But now comes our correspondent to point out a flaw in the reasoning. He argues that when the water in the rivers is spread upon the land and used in irrigation it is all evaporated, and the ultimate effect will be so to increase the moisture content in the air of the arid region as to render it no longer arid. In other words, will not the irrigation work of the Far West increase the rainfall and thus the available supply of water for irrigation, which will again still further increase the rainfall, and so on? Our correspondent puts it mathematically, as follows:

Starting with an original quantity Q: 1st step: Q; 2d step: $Q + \frac{Q}{3} = \frac{4}{3}$ Q; 3d step: $\frac{4}{3} Q + \frac{4}{9} Q = \frac{48}{27}$ Q; 4th step: $\frac{48}{27} Q + \frac{16}{27} Q = \frac{64}{27} \times Q$ (or already more than double).

Now we do not like to throw cold water on our correspondent's plan—or, speaking more accurately, to dry it up. It would be a very fine thing if irrigation water *would* go on forever, like the brook; and if it were indeed within the power of mankind to create such a transformation of climate, it would be a feat easily surpassing in benefit to the race all recorded human achievements.

We greatly fear, however, that the facts are all against the probability of any such result as our correspondent suggests. In the first place, it is a matter of common observation that local evaporation has practically no influence whatever on local precipitation. There are great areas of country which border tropical seas, from which evaporation is continuous and enormous, and yet they are practically rainless. The region bordering the Red Sea and the southern shore of the Mediterranean is a case in point. So also is the land adjacent to the Gulf of California. Compared with such evaporation, the water discharged into the air from the entire possible irrigated area of the West will be trifling.

But there is even stronger evidence that our correspondent's suggestion has "nothing in it." Take a map of the western United States and note the fact that at the present time practically all the rainfall on that great region between the Rocky Mountains on the east and the Cascade range on the west is evaporated or absorbed and does not reach the ocean. We say practically all, for, of course, there is at some seasons water flowing in the Rio Grande; there is some run-off through the Colorado to the southwest and the Snake River to the north. But the whole amount of this run-off is a mere trifle in comparison with the vast area which it drains, so small that if it were all spread equally over that region it would have practically no effect on the aridity.

Our London contemporary, "The Engineer," shows a curious lack of perspective and indulges in some lively geographical jumps in its New Year's portrayal of water supply activities "Abroad." We quote as follows:

> Abroad there are evidences of much activity in waterworks engineering. A large number of towns in the States are installing slow sand filters, and a large amount of money is being laid out. A huge scheme is proposed for New York. It is to tap the great upper lakes, and to bring the water by gravitation to New York, where it would arrive under 200 lbs. pressure. The amount of water abstracted would only equal, it is said, one-four hundredth of the water going over Niagara. The cost is put at £30,000,000. They do some unlikely things in America, but it seems improbable that this particular scheme will ever be carried out—at any rate for many years to come. Meanwhile, work on the New Croton dam is nearly completed. Calcutta has adopted plans for increasing its water supply. Sydney is constructing the Cataract dam 145 ft. high to by-wash level, and 723 ft. long. The reservoir will hold 18,000,000,000 [imp.] gallons. Morgenil—Côte d'Or—is improving its water supply at a cost of 1,000,000f. Los Angeles has decided on a scheme to bring pure snow water 240 miles from Owen's River. It will have to pay $23,000,000 for it. Bassett, Nebraska, is constructing new water-works. Poughkeepsie, the first American city to have slow sand filters, is largely increasing its installation of them. Manila is constructing a dam, laying 10½ miles of 42-in. pipes, and constructing 4½ miles of tunnel and open cutting, distributing reservoirs, etc. Burlington, Vergennes, St. Johnsburg [St. Johnsbury], Enosburg Falls, and Swanton are engaged on either purifying their water supplies or seeking fresh sources.

It is many a "far cry" from New York to Calcutta, to Sydney, to Morgenil, to Los Angeles, to Bassett, Neb. (Population, 270, by the U. S. Census of 1900!), to Poughkeepsie, to Manila, and finally back to those scattering Vermont cities and villages of 20,000 to 2,000 population. How delighted Bassett, Neb., will be one of these fine winter mornings when it awakes to a knowledge of its fame; that it, alone, of all the hundreds of towns engaged in water-works construction in the fifty states and territories outside of New York, Vermont and California, should have been singled out for mention in a London journal!

As to the improbability that New York will carry out the water supply scheme outlined in the quotation, we quite agree. Our contemporary has evidently confused one of the perennial schemes of the fertile writers for the daily press with the plans recently recommended by the permanent Water Supply Commission. These plans involve an estimated expenditure of $161,000,000 for a supply from the relatively nearby Catskill Mountains. A supply from the "upper great lakes" would involve a conduit some 450 miles long, and as the elevation of those lakes is considerably less than 600 ft. above tide water at New York, it would, to say the least, be an expensive problem to deliver to that city 500,000,000 gallons a day under a 200 lbs. gravity pressure.

PROPOSED NEW METHODS OF SUBAQUEOUS TUNNEL CONSTRUCTION.

Two interesting substitutes for ordinary tunneling methods for subaqueous railway crossings of streams are suggested by the plans published in our last issue of the new Seine River tunnel work at Paris, and of the proposed Michigan Central R. R. tunnel at Detroit. In the Paris work the

crossing is being constructed by sinking completed sections in sequence in the form of caissons; in the proposed work at Detroit it is planned to sink timber or steel forms on a prepared bed and cover them with concrete deposited under water. Any discussion of these projects at the present time must necessarily be mere speculation, but they can hardly be passed without some comment.

The idea of using caissons sunk end to end and "joined up" by suitable water-tight joints to form a subaqueous tunnel is not new. Some twenty years ago if memory serves us truly this method was adopted in constructing a small tunnel in Australia. We cannot lay hands at once on a record of this work, but it proved so successful that soon afterwards a similar plan was advanced for constructing a tunnel crossing of the Thames at London. Nothing came of the Thames River project nor of a later plan of the same general character put forward by Prof. Winkler for the Vienna underground railway crossing of the Danube. With the possible exception of the Australian tunnel mentioned above the Metropolitan Railway tunnel under the Seine at Paris described in our last issue is, therefore, the first to be constructed by what we may call the caisson method.

The methods proposed for the construction of the Michigan Central R. R. tunnel at Detroit differ radically from the caisson method in character. They have been designated trench methods by the engineers, and this term serves as well perhaps as any to define them. A closely comparable method of construction has long been used in laying water pipes across the beds of streams, but further than this the plans have, we imagine, no precedent.

In reviewing these brief statements two questions naturally arise: What is to be gained by substituting these untried methods for the ordinary tunneling methods proved by long experience? What are the chances that either method of construction will prove structurally practicable? As stated before, the answer to these questions must for the present be based on mere speculation.

The first question may be answered in the same words for both methods. By constructing the subaqueous route on the bed of the stream there is a decided reduction in the depth to which it is necessary to carry the tracks below the normal surface approach grades. Other possible advantages may be of doubtful certainty, but there can be no question that by either the caisson method or the trench method a decided saving is possible both in the length of tunnel required to make the crossing and in the elevation which it will be necessary to overcome in operating through it. It is perfectly possible to present proofs ad infinitum of the importance of this advantage, but the railway operating official has no need of them and others no concern in them. It is enough perhaps to observe that a material gain in this matter has been all the warrant necessary for the trial of an expensive experiment by both the Paris Metropolitan Railway engineers and the engineers of the Michigan Central R. R.

Now, as to the structural practicability of either or both methods there does not seem to be much reason for doubt. It is true, of course, that neither method has been proved, but the same statement was not so very long ago true of the shield system of tunneling. Caissons have been sunk time and again for bridge piers with great exactitude of location in water that was both deep and swift. They should not be any more difficult to sink, it would seem, when used for tunnel construction. At the Seine Tunnel work absolutely no difficulty beyond that usual to such work has been experienced in putting down the single caisson so far placed or in keeping it to line and grade. Indeed, the only difficulty that seems likely to be possible comes in the task of connecting up the adjacent caissons to form a continuous structure. In the Paris Metropolitan Railway work it is proposed to make this connection by means of small movable caissons, and this seems likely to prove an awkward process from all accounts.

In the method proposed for the Detroit River tunnel forms of suitable lengths are to be sunk to the bottom of the river and filled around with concrete. None of the items of this task seem to offer special difficulty. It is an ordinary task to dredge a trench to grade across the river bottom and the filling of this trench with a flooring or footing of concrete on which to rest the forms presents no complication. The cradles or blocks for alining the forms and holding them in place may be readily placed by divers. The sinking of the forms themselves may offer more difficulty, but hardly any that cannot be overcome by cutting down the length of section handled at one operation. As to the placing of the concrete around the forms everything should be plain sailing if ordinary precautions are used. The proposed plan for joining up the consecutive sections is simplicity itself, by leaving a space between adjacent ends of forms to be filled with concrete as the form is enveloped, the task of connecting one section with another is simply that of breaking through a partition of concrete.

Basing their estimates upon careful comparative studies, the engineers of the Detroit River work figure a decided saving in first cost by using the trench method instead of the shield method of construction. Without equally careful expert investigation one is hardly warranted in questioning this conclusion, but even were the cost materially greater it would be more than compensated for by the saving in grades wrought by the shallower location.

LETTERS TO THE EDITOR.

The Origin of the Plan of Building Subaqueous Tunnel Sections as Caissons.

Sir: Relative to Mr. Fitzpatrick's statement, in Engineering News of Feb. 15, that the credit for conceiving the idea of using subaqueous tunnel sections temporarily as caissons is "all mine," I want to explain that the scheme was devised during a general discussion of the subject between Mr. F. C. Osborn, M. Am. Soc. C. E., of this city, and myself; and that neither of us really knows which is to blame. At any rate, I don't want it all.

The coincidence with the French work is quite remarkable, especially when it is known that their exact scheme was entertained by us but abandoned, on account of the expensive filling necessary under a permanent floor.

Fred W. Lepper, M. Am. Soc. C. E.
504 Chamber of Commerce, Cleveland, O., Feb. 17, 1906.

Fall of a Dumping Bridge.

Sir: In connection with some grade separation work in Cleveland, the Pennsylvania Co. is making a fill across a ravine about 75 ft. deep, the work being done by Williams Bros. & Morse. When the toes of the two opposite slopes about met at the bottom of the ravine a suspension bridge was built to facilitate the dumping of earth in the ravine. Two main cables, 1¼ ins. diameter, were passed over two cribbed up towers, about 200 ft. apart, and from these cables a rough timber floor system was laid. On this was a track of about 3-ft. gage.

Yesterday afternoon a train of six or seven 6-yd. dump cars was pushed onto this bridge, and when the front car was about in the middle of the span one cable parted, dropping all the cars to the bottom, about 60 ft. down. The small saddle-tank engine, barely off of terra firma made a manful effort to get back out of trouble, but the weight of the loaded cars dragged it down. The fireman and engineer jumped when they saw there was no hope of saving the engine, and so no one was injured.

Yours truly, W. E. Phelps.
96 Eastman St., Cleveland, O., Feb. 11, 1906.

Civil Service Examination Questions for Assistant Engineers.

Sir: I enclose a copy made from memory of an arithmetic examination held on Feb. 13.

This examination was held for assistant engineers for the Rapid Transit Commission, $1,200 grade, and the time allowed for this paper and a report on one of three given subjects, covering from two to four pages, was two hours. Part of this same was occupied with announcements and the giving out of papers.

As most of the 150 or more men who took this examination did not finish the technical paper until two o'clock, if they desired any lunch the time had to be taken out of this two hours. The questions are made out from memory but have been checked in all substantial details by several men who took the examination.

I will be glad if you can find space in the Engineering News to print these questions with your comments on the man who wrote them. They would also be good practice for young college engineers who have and yet forgotten the arithmetical rule to find the cube root of a number.

Very truly yours,
C. S. W.

New York City, Feb. 16, 1906.

EXAMINATION PAPER IN ARITHMETIC.

1. Divide 14 by .7684. Multiply .69874 by 4502. Reduce $10^{11}/_{32}$ ins. to decimals.
2. Extract the square root of .000729 and of 37 ft. 3⅝ ins. Extract the cube root of .58764 and of 2.
3. If a point is 120 ft. from a building, the line of sight to the top makes an angle of 60° 30' with the horizontal, what is the height of the building?
4. How would you obtain the length between two inaccessible points across a river? Assume distances and angles and solve completely.
5. What is the cost of 75 cu. yds. of concrete and the quantities used, cement at $0.48 a sack, sand at 0.94 a cu. yd. and stone at $1.84? Sand is 35% voids and stone is 45%. Allow 5% for water.
6. What is the cost of 473 1-in. round iron rods 10 ft. 8⅝ in. long. Iron at $43.86 a ton? 5,835 cu. ft. of concrete at $5.64 a cu. yd.
7,638,472 ft. B.M at $27.96 a thousand. 1,573 sq. ft. of asphalt at $3.67 a sq. yd.
7. How many ft. B.M. in
48 pcs. 12 × 12 ins. — 24 ft. 6 ins.
276 pcs. 8 × 10 ins. — 14 ft. 9 ins.
1,642 pcs. 4 × 6 ins. — 16 ft. 4 ins.
776 pcs. 2 × 4 ins. — 22 ft. 8 ins.
17 pcs. ⅞ × 3½ ins. — 9 ft. 4 ins.?
8. If a line is measured as 1,768.40 ft. and the tape is then found to be 0.3 of one inch too short, what is the true length of the line?
9. What is the prismoidal formula? Solve an example completely assuming all dimensions.
10. Give the weight of a cubic foot of: Water, Cast Iron, Wrought Iron, Steel, Sand (dry and loose), Asphalt, Concrete, Gravel and Portland Cement.

(NOTE.—No tables whatever were allowed, and by special announcement the use of a slide rule was not permitted.)

Design of Retaining Walls.

Sir: In the Nov. 16, 1905, issue of Engineering News, Mr. Chas. Worthington criticizes an article by Mr. H. P. Boardman on the Design of Retaining Walls, which appeared in Engineering News of Aug. 17, 1905. Mr. Worthington takes exception to two assumptions made in the article referred to, namely (1) That the wall rests on an unyielding base, and (2) That moments be taken about toe of wall. In this connection he refers to the fact that the second assumption was also made by the writer in the design of a wall recently built by him, and described in the March 9, 1905, issue of Engineering News. Mr. Worthington's letter has been called to the writer's attention upon his return from a protracted stay in the Rocky Mountains, hence the tardiness of these remarks.

The writer contends that the use made by him of the second assumption, above referred to, in the design of the 40-ft. Seattle wall is legitimate and consistent. In order to arrive at a knowledge of the approximately proper width of base to provide in the structure, a moment equation was established, one side of which consisted of the moment produced by the assumed lateral thrust multiplied by three as a "safety" or "ignorance" factor, as one prefers, while the moment of the backing resting on top of the reinforced base, comprised the other side; the point of toe being assumed as the moment center. The moment of the concrete wall itself was neglected, which is an error on the side of conservatism so far as investigation as to stability is concerned. It would seem that the question as to whether or not, under the conditions assumed, the concrete at point of toe would crush, or the bearing power of foundation at that point be exceeded, is a matter of no moment in this connection. The object sought through this equation was to determine a width of base such that tipping would, beyond a doubt, be prevented, and an entirely separate and independent investigation was then made as to the intensity of compression at point of toe. Also, in detailing the toe itself the wall was considered to be on the verge of tipping and its whole weight, plus that of the backing superimposed on base, was assumed concentrated at point of support, namely the edge of toe. This assumption results in a working moment at face of wall, where exists the critical section, far in excess of that which would actually occur under the conditions named, and is on the side of safety. Here again we are not concerned with the question as to whether or not the crushing value of the concrete, or the bearing value of the foundation at edge of toe, is exceeded, and the fact that such failure would result does not destroy the utility of the assumption for the purpose in hand, namely, the detailing of the toe to resist bending moment.

It would seem that the proper course to pursue in the design of such structures as earth retaining walls is to make sure that the assumptions as to external forces and their effects, in each particular case at hand, are such as may be considered radically on the side of safety in the best possible judgment of the engineer. The Seattle wall was designed and built in accord with such ideas, and in this case, as in that of probably every other earth retaining wall ever built, no strict compliance with

any existing theories is professed, nor was such a state of things desired or sought. The methods used are, nevertheless, believed to be consistent, sound and safe.

Yours truly,

C. F. Graff,

Asst. Engr. Great Northern Railway.

Spokane, Wash, Jan. 19, 1906.

Notes and Queries.

H. S. H., Philadelphia, Pa., writes:

In Mr. H. S. Stott's paper on "Power Station Economics," in your issue of Feb. 8, in the table giving the distribution of the available heat in the coal, the loss in ashes is given as 2.4%. Is not that unusually low, only 240 B. T. U. per lb. of coal? The appearance of the ashes rejected by automatic stokers would seem to indicate that considerably more energy than this is lost in the ash pit.

The record of fuel loss in the ash is certainly low; much better we should judge than the usual average in power station boiler rooms. We may add the caution, however, that the hasty reader must not make the error of confusing the above percentage of heat loss in the ashes with the usual figure of percentage of unburned fuel contained in the ashes.

For example, if we assume that the coal burned contains 10% of ash, then 100 lbs. of coal when burned will leave 10 lbs. of ashes. If 2.4% of the heat in the coal is lost in the ash, then 2.4% of 90 lbs. = 2.16 lbs. = amount of unburned coal left in the ashes. The total quantity taken out of the ash pit will be 10 lbs. of ashes + 2.16 lbs. of coal = 12.16 lbs., and the percentage of coal in this mass will be 12.16 ÷ 2.16 = 17.7%.

This computation does not take into account the heat loss in the ashes due to their removal from the ash-pit when hot; but ash has a low specific heat and the loss in this way under ordinary conditions is too insignificant to consider.

CONFERENCE ON UNIFORM CLASSIFICATION OF MUNICIPAL ACCOUNTS AND COMPARABLE MUNICIPAL STATISTICS.

Under the auspices of the United States Census Bureau there was held at Washington, D. C., on Feb. 13-14, a conference on uniform municipal accounts and statistics. Two years ago a similar conference was held at Washington, and some of the ideas there brought out have been utilized by the Census Bureau in its formulation of schedules for inquiries. The object of these conferences, aside from promoting uniformity, is to bring the Census Bureau into close touch with the fiscal officers and others having to do with municipal accounts and statistics, and to give the various officials an opportunity to become acquainted and interchange ideas. The conference just held was attended by perhaps fifty people, not counting a number of agents of the Census Bureau. Some fifteen different States were represented, including such distant ones as Minnesota, Nebraska, Wyoming, Colorado and South Carolina.

The conference was welcomed by Mr. McFarland, one of the Commissioners of the District of Columbia, and also by Mr. S. N. D. North, Director of the Census. Mr. North stated that he understood the object of the conference to be the standardization of municipal statistics. There are in the United States 175 cities of 30,000 population and upwards, constituting the most magnificent group of municipalities in the world. But upon these cities there rests the stigma of extravagance in their expenditures. The total annual expenditures of the group of cities is some $765,000,000; their total indebtedness is $1,500,000,000, and this is perhaps increasing at the rate of $150,000,000 a year. There is great need of rendering comparable the cost of municipal services in different cities, so that if a given service in any one city greatly exceeds the cost in others it may take steps to learn the reason why.

Following the remarks by Mr. North, Dr. E. M. Hartwell, of Boston, Secretary of an advisory committee selected at the first conference, presented a review of the movement for uniform municipal statistics. The object of the present conference, the speaker said, was to consider what comparable statistics really are. The old Greek maxim, "Know thyself," applies to local officers and cities, and until this knowledge is secured it is impossible to draw proper comparisons between one's own city and another.

A telling point made by Dr. Hartwell was the following: "'Business methods' in municipal affairs does not seem to be so desirable as it did before the recent investigation of private corporations in New York. Before long, our municipalities may point the way for private corporations to conduct their business."

Mr. L. G. Powers, of the Bureau of the Census, who has charge of investigations concerning municipal affairs, spoke upon past and present publications of the Census Bureau on municipal statistics. Bulletin 20 (for the years 1902-3) will soon be followed by a somewhat similar bulletin for 1904, but containing financial statistics only. In connection with this work, it has been necessary to master the meaning of the terms used in various cities, and also the laws of the several States bearing on municipal revenues. Some important work on this subject, including also municipal franchises, has been done by Prof. Carl Plehn, of the University of California, and will be published in detail later.

The work of the Ohio bureau for the control of municipal accounts was explained by Mr. Joseph T. Tracy, of Columbus, O. This work was begun in July, 1903. A uniform system of revenue and expense accounts has since been installed in the 71 cities of the State, which include all places of 5,000 and upwards. This system worked so well that within ten days after the close of the year 1904 more than half of the city auditors made very satisfactory reports on revenue and expense to the central bureau. The bureau has given a large amount of attention to the accounts of the 88 counties of the State, and has completed forms for school, township and village accounts.

It has been the practice in Ohio to base bond issues for betterment improvements on the preliminary estimates of engineers, and this has led to misappropriation of funds. In one city some work estimated as rock excavation turned out to be earth excavation instead, so the total cost of the improvement in question was but 60% of the estimate. Bonds had been issued to the full extent of the estimate, and frontage or other special assessments, also based on the estimate, were levied against the properties benefited, and collections went on regardless of the discrepancy until the facts of the case were brought out by the State bureau, and the property owners were thus led to protect their interests. In such cases as this the excess of bond proceeds over actual cost is turned into the general treasury.

Columbus is the only city in Ohio which has ever attempted to make a statement of its assets and liabilities. In formulating a system of accounts designed to show the assets and liabilities of all municipalities of the State, the bureau is in perplexity over the method to be employed in valuing municipal improvements. For instance, the water-works of a certain municipality have cost in actual cash outlay $240,000, are locally valued at $300,000, but a private company has offered to buy the works for $600,000 and to give a guarantee that it will not increase the rates over those now charged. Which of these three valuations, Mr. Tracy asked, should be used? Another question that arises is whether or not there shall be an allowance for depreciation.

Contrary to the opinion of a number of city fiscal officers, as expressed at various times during the conference, Mr. Tracy held that every municipality should set up an account showing the cost of construction of such non-revenue producing improvements as bridges, sewers and street pavements.

In the course of the discussion of Mr. Tracy's paper, the fact was brought out that the city of St. Paul balances every one of its appropriation accounts daily, thus leaving no excuse for overrunning the appropriation to any given account, which overrun is contrary to law. This plan also makes every clerk keep his work absolutely up to date.

A discussion on the topic of keeping accounts of municipal industries and public service corporations, so that the cost of construction and of operation and the value of the services rendered may be compared, was opened jointly by Mr. M. N. Baker, of the editorial staff of this journal, and by Mr. Harvey S. Chase, a public accountant, of Boston. The value of the service rendered or the cost of the service was taken up by Mr. Baker. The first essential is to ascertain the gross cost of a given service, such as waterworks, regardless of to whom the service is rendered. This cost must be accurately divided between construction or capital charges and maintenance or operating expenses. Troublesome questions arise as to whether or not account shall be taken of the interest charges on redeemed bonds under municipal ownership, and there is also a difficulty concerning allowances to be made for depreciation. Whatever the opinion may be on such questions as these, it is certainly possible to separate the capital charges from all other charges, in so far as actual money transactions are involved. Some of the other questions, it is evident, are what accountants term bookkeeping items.

The gross cost of the service having been determined, it is necessary to divide this into the cost due to service rendered (1) private consumers and (2) municipal or public consumers, such as water furnished for fire protection, street sprinkling, etc. In this connection the importance of separating construction and operating charges becomes evident, since a large part of the first

SUMMARY OF REVENUES AND EXPENSES OF PUBLIC SERVICE INDUSTRIES UNDER EITHER MUNICIPAL OR PRIVATE OWNERSHIP.

[a] INCOME.		
Sales of Product, (Water, Electricity, Gas, etc.)		$
Less Rebates, Refunds, Discounts, etc.		$
Net Income from Sale of Product		$
[b] EXPENSE.		
1. Expense of Manufacture (or "Supply" for Water)	$	
(M. o.) Operation (Running Expense)	$	
(M. m.) Maintenance (Repairs)	$	
2. Expense of Distribution	$	
(D. o.) Operation (Running Expense)	$	
(D. m.) Maintenance (Repairs)	$	
3. General Expense	$	
Not including taxes, insurance, damages, guaranty, depreciation, dividends, interest or sinking funds.		
Total "Expense"		$
Income, less Expense		$
[c] CHARGES ON ACCOUNT OF REVENUE.		
Taxes and Franchise Payments	$	
Insurance, Fire, Liability	$	
Damages and Extraordinary Legal Expenses	$	
Guaranty (Against Shrinkage of Current Assets)	$	
Depreciation (Against Shrinkage of Capital Assets)	$	
Total "Charges against Revenue"		$
Income, less Expenses and Revenue Charges		$
[d] CHARGES ON ACCOUNT OF CAPITAL.		
Dividends	$	
Interest (net)	$	
Sinking Funds	$	
Amortization of Franchises	$	
Total "Charges on Account of Capital"		$
Surplus Income from Sales of Product		$
[e] INCOME FROM OTHER SOURCES		$
Total Surplus Income		$

cost of a water-works plant, for instance, is due to the increased capacities required for fire protection. All municipal departments should be charged for services rendered by any other department.

Per capita figures of cost are seldom of much value for comparative purposes, and in their stead other unit prices should be ascertained, such as the cost of water per thousand gallons, or the cost of lighting per hour of time and candle power. Even such figures as these are not strictly comparable as between different cities, owing to variations in such local conditions as the cost of coal, hours and rates of wages for labor, whether or not, in the case of water-works, the supply is delivered under sufficient head to make fire engines unnecessary.

The attention now being given to municipal ownership questions makes it more essential than ever that municipal accounts should be so kept as to be comparable with the accounts of public service corporations rendering the same services. The investigation of municipal ownership, international in character, just started by the National Civic Federation, makes it all the more desirable that municipal accounting for public service industries be put on a comparable basis.

Mr. Chase opened his remarks by referring to the municipal ownership inquiry of the National Civic Federation, mentioned just above. Accounting or reporting schedules having been worked out heretofore by the American Gas Light Association, the National Electric Light Association, the Street Railway Accountants' Association, and the New England Water-Works Association. An attempt is now being made to bring these various schemes into harmony. The result of this attempt was submitted in the form of a single sheet, summarizing the revenues and expenses of such industries. The essential features of this sheet (original 8 × 14 ins.) are reproduced on the preceding page.

After receiving criticisms from the conference, Mr. Chase proposed to pass the schedule on to the American Accountants' Association for criticism, and then to the National Municipal League Committee on Uniform Accounts and Statistics, before putting the schedule into final shape for use by the committee of the National Civic Federation. The consolidated or summary schedule was thought to be suitable for all four of the services indicated, but would, of course, have to be backed up by detailed accounts for gas works, electric lighting plants, street railway systems and water-works.

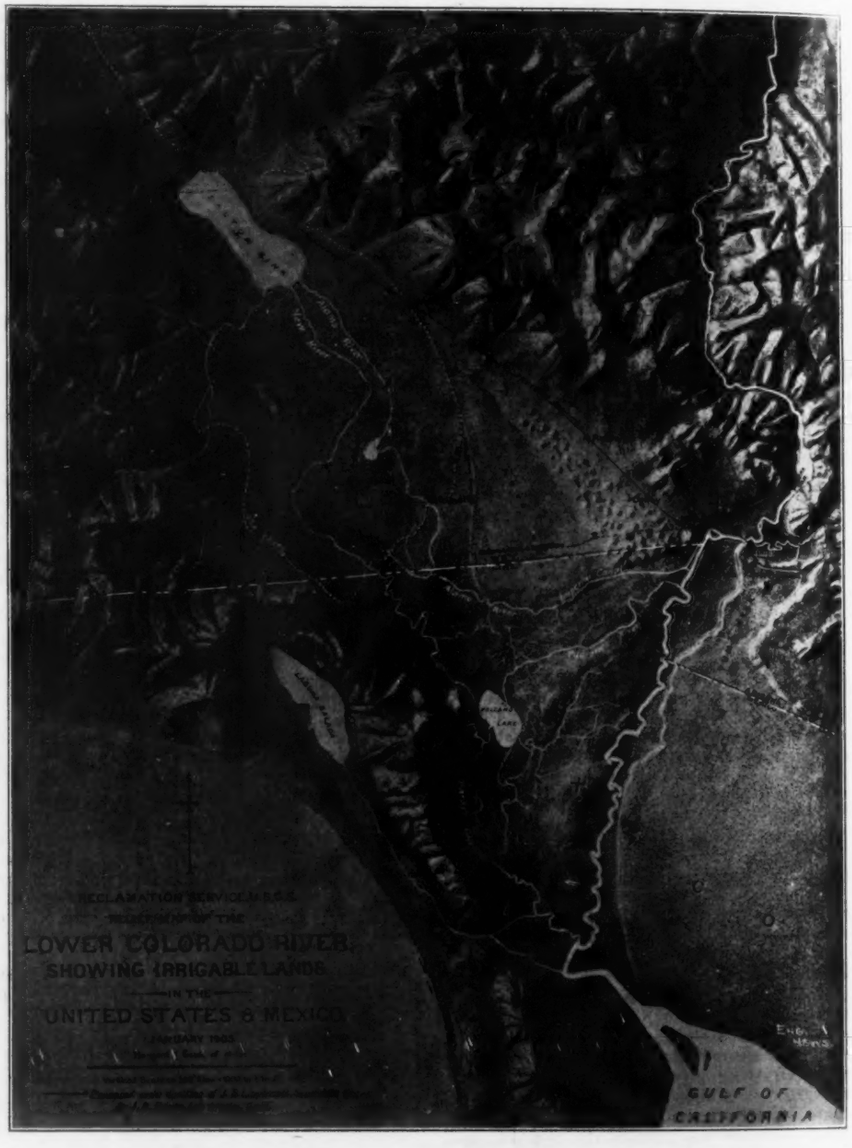
An elaborate paper on terminology and classification of municipal accounts was presented by Dr. F. A. Cleveland, of New York City. The author, in opening, dwelt upon the necessity of a common language, in order that there might be a common understanding of municipal accounts and statistics. Standardization is an outgrowth of the municipal reform movement now in progress.

The fifth and final session was devoted to the balance sheet of cities and to the practical value of revenue and expense accounts.

THE BREAK OF THE COLORADO RIVER INTO THE IMPERIAL VALLEY AND SALTON SINK.

The flooding of many thousands of acres of irrigated land, the destruction of hundreds of homes, and the raising to sea level of the waters of the famous Salton Sink from its depression of — 287 have been threatened for some months past as the result of cutting a short emergency irrigation canal from the lower Colorado River. For some unexplained reason the ditch named was not provided with headgates, and the small ditch was soon enlarged by erosion so as to divert a large part of the flow into the Imperial Valley and on down to the Salton Sink. The salt works on the shore of the Sink were soon flooded, as also some miles of track of the Southern Pacific Railway, necessitating the relocation of the latter. Attempts to throw the river back into its proper channel have thus far only widened and deepened the diversion channel and made new cut-offs that facilitated the passage of the river water on towards the Sink.

As many of our readers know, the Colorado is one of the largest rivers of the United States, having a drainage area, according to the U. S. Geological Survey, of 225,049 sq. miles. Rising in Wyoming, as the Green River, and flowing through some of the deepest canyons in the world, the river finally emerges near the Arizona-California-Mexico boundary, and after flowing across a great sandy desert, mostly in Mexico, it discharges into the Gulf of California. In past ages, it is supposed, this Gulf extended far northward into California, but in the course of centuries the debris brought down by the river built up the river bed and left a large inland sea. This sea, in turn, has been evaporated until, within the knowledge of civilized man, it has been represented by a shallow body of water, backed into the mountains some 60 miles from the river—as shown by the accompanying reproduction of a relief map, made by the U. S. Reclamation Service. In times of flood large areas of land along the west side of the built-up bed of the river are overflowed, and when the overflow is sufficient well-defined streams find their way towards and sometimes into the Sink, such as the Alamo River, or else onward to the Gulf, as the River Padrones to Volcano Lake and Hardy's Colorado from there to the Gulf. An unusually high flood in 1891 forced its way from Volcano Lake to Salton Sink, in a course generally parallel to the Alamo River. This water course is named New River and carried water to the Sink in 1861 and 1840, also.



Observations on the volume of silt carried by the Colorado River show that it is sufficient to cover 53 sq. miles to a depth of 1 ft. of alluvial soil in a single year. The lowest point of the flat ridge between the Sink and the Gulf is about 30 ft. above sea level. The old beach line, at a slightly higher elevation, is now clearly traceable. The tract of land now below sea level is about 1,000,000 acres in area and about 90 miles in length. The population within this area is estimated at from 6,000 to 8,000. About 100 miles of the main line of the Southern Pacific Ry. and some 40 miles of branch line are located beneath sea level.

The total fall from the point where the Colorado River crosses the international boundary line to the bottom of the Sink is about 400 ft., and the distance is 130 miles. This gives a fall of about 3 ft. per mile, as compared with a river fall of only 1.25 ft. per mile for a distance of several hundred miles above the Gulf.

According to Mr. J. E. Roadhouse,* the Colorado River Irrigation Co. was organized in 1893, to divert water from the Colorado River, below Yuma, for irrigation in the Salton Basin. In 1896 this company, which had done nothing but make surveys, was succeeded by the California Development Co. On April 25, 1899, the last-named company filed on 10,000 cu. ft. per sec. of

*"Irrigation Conditions in Imperial Valley, California." Based on field observations made in the summer of 1903. Published in Report of Irrigation and Drainage Investigations, 1904, Office of U. S. Experiment Stations, Bulletin 158.

water to be diverted from the Colorado River at a point some 1.5 miles above the Mexican boundary. Here about 1901 it dredged the upper ten miles or so of the Alamo River channel for use as its main canal. As may be seen from the map, the combined canal and river makes a detour into Mexico, then back into California, before reaching the Imperial Valley. This fact made the organization of a Mexican company necessary, but the latter was controlled by the California Development Co.

During the irrigation season of 1904, as we understand it, there was a shortage of irrigating water in the Imperial Valley, owing to the silting up of the upper part of the Alamo Canal. To give immediate relief, a cut-off canal, some 3,300 ft. long, 50 ft. wide and 8 ft. deep, was dug in October, 1904, between the Colorado River and the canal, as shown on the map. This canal is located in Mexican territory, and, it is said, was dug without obtaining consent of the Mexican Government. The Government of the United States, obviously, was not responsible for the cut-off, nor for the disaster that followed, and has no control over remedial measures.

The winter of 1904-5 was remarkable for heavy winter floods in the section under consideration. Beginning on Dec. 22, 1904, a half dozen floods followed in rapid succession, coming mainly from the Gila River, which joins the Colorado near Yuma, Ariz., and below the Yuma dam, now being constructed on the Colorado River. These floods, unhindered by controlling works, widened and deepened the cut-off channel to the Alamo Canal, and thus the waters of the Colorado found their way, in increasing volume, to the Salton Sink. Late in February, 1905, a member of the editorial staff of this journal, in passing west over the Southern Pacific, was surprised to find a large body of water in the "Colorado Desert." The winter floods, perhaps because heavily silt-laden, caused little erosion in the canal, but when the heavy summer rise occurred, in May and June, 1905, the increased volume and velocity of flow were accompanied by less silt than during the earlier overflows, much additional erosion took place and the diversion of water to the sink was materially increased. On June 1, 1905, the river was discharging a total of 61,500 ft. per sec., of which 5,360 sec. ft., or 11%, entered the canal. On June 30, with the same river volume, 13,960 sec. ft., or 22% of the total flow, went through the canal. On July 30, the canal was taking 86% of the river flow, or 15,020 out of 17,500 sec. ft. On Oct. 25, 1905, the full river discharge, which was then 6,000 sec. ft., was going to and through the canal.

During 1905 ineffective attempts were made to turn the overflow back into the river. Meanwhile, as we understand it, the Southern Pacific assumed control of the California Development Co., and the fight against the river was continued by the engineering forces of the railway company. Late in November, 1905, a diverting dam of brush, wire, piles and gravel, designed, it appears, to throw the river away from the entrance to the cut-off canal, had been nearly completed when another flood rushed down the Gila, raised the Colorado some 14 ft. in 24 hours, according to reports, swept away the diverting dam and greatly widened and deepened the already enlarged cut-off canal. It is said that the work demolished by this flood cost $25,000. The width of the channel, as left by the flood, is variously reported as from 600 to 2,000 ft., but presumably the latter applies to a stretch extending a short distance from the original entrance to the cut-off. Below the junction of the cut-off with the Alamo Canal the width of the latter, it is reported, was increased to 300 ft., from 85 ft. It is estimated that the flood flow at this time was more than 100,000 sec. ft., and that one-fourth of this was diverted by the canal. As the flood subsided the relative volume of flow through the canal increased. This indicates that although the new channel is not yet capacious enough to carry the entire flood flow yet it has become the main channel of the river.

With the hope of diverting some of the flow back to the Gulf, a short channel was dug from the Alamo canal or river to the Padrones River (see map), not far from the Colorado and some nine miles down the Alamo Canal. This cut was designed to turn water into Volcano Lake. A dam was built, or proposed, across the New River outlet of the lake, so the lake would discharge to the south and east, into the Gulf, through an old channel called Hardy's Colorado, instead of to the northwest, through New River, into Salton Sea. The result was quite different: the Padrones broke for itself a new channel (see

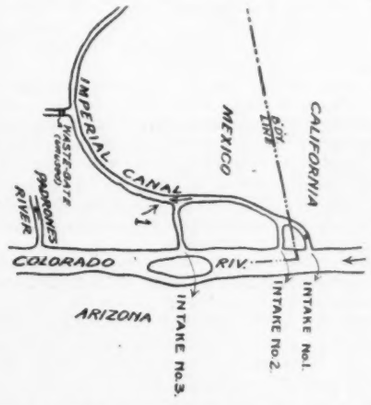


Fig. 2. Sketch of Intakes of Imperial Canal, California Development Co.
(Reproduced from article by Edwin Duryea, Jr., in "Out West" for January, 1906.)

map) across country north of Volcano Lake, into New River, and thus, in defiance of man, but true to nature, the water found its lowest level in the Salton Sink.

Efforts now in progress to get the Colorado back into its proper channel, according to the Los Angeles "Times" of Dec. 10, 1905, and the San Francisco "Chronicle" of Jan. 19 and 20, 1906, include a headgate at the entrance to the Alamo canal or river and a headgate and long levee at the head of the cut-off. The main or upper headgate, it is said, will be of concrete and steel, on rock foundation, with a length of 175 ft. between abutments. The lower headgate is described as being built in an excavation, in a tongue of land between the cut-off and the Colorado River. It is said that it will be about 200 ft. long, flanked by wing dams, and, eventually, by the levees already mentioned.

The contract for the main or upper headgate calls for its completion by April 1, from which time until well into June, when the snow-water floods come down, it is hoped that the Colorado will be low enough to facilitate the plans for completing the work at the lower headgate. These plans include (1) turning as much as possible of the flow of the Colorado through the main or upper headgate, which has a calculated capacity nearly equal to the dry weather flow of the river; and (2) turning the remainder of the flow through the lower headgate, and then constructing a levee across the wide, flood-enlarged entrance to the cut-off canal.

The president of the California Development Co. is now Mr. Epes Randolph, formerly head of the Southern Pacific lines in Arizona. Mr. J. D. Schuyler, M. Am. Soc. C. E., has been employed as consulting engineer. Mr. J. S. Tolin is engineer in charge of headgate construction.

About the middle of January, 1906, Salton Sink was described as a body of water 10 to 18 miles wide, 45 miles long, with a maximum depth of 23½ ft., and with the water rising from ½ to ¾-in. per day. When the heavy floods are on the rise is said to be 2 ins. a day. The works of the New Liverpool Salt Co., on the shore of the Sink, as it existed before the floods poured in, are now submerged up to the roof of the buildings.

A press dispatch dated Feb. 8, 1906, stated that the Southern Pacific had just completed some 40 miles of new track, to get above the water that is raising the level of the Salton Sink. The new track, it is said, leaves the main line at Mecca, 13 miles east of Indio, and joins it again at Volcano. It is also said that the new location is 50 ft. higher than the old main line and about two miles from the present water level of the Sink.

Should the efforts to control the river fail, and the June floods pour in, large areas of land, much of which has been under irrigation, would be flooded, but a large part of the Imperial Valley, as we understand it, would be only temporarily effected by the stream flow of one season. How long a time would be required to swell the Salton Sink to its original or sea level, thus covering an area many square miles in extent, is an interesting subject for speculation; all the more interesting in view of the enormous evaporation in what was formerly termed Death Valley. From the paper by Mr. Roadhouse, already mentioned, it appears that the total rainfall at Imperial, Cal. (see map) in 1902 was 1.3 ins. The mean temperature for the year was 73.5° F., but the maximum temperature in the same year was 123° F. The total evaporation at Yuma, Ariz., in 1904, was 82.32 ins. The rainfall was only 1.43 ins., giving a net evaporation of 80.89 ins.*

The approximate area of the Salton Basin is 1,000,000 acres up to the sea level and 1,220,000 acres to the 30-ft. contour, already mentioned as being the lowest level in the divide. Assuming that the basin is in the form of an inverted cone its capacity, up to the two levels named, would be 96,000,000 and 129,000,000 acre-feet, respectively. For the past 11 years the mean annual discharge of the Colorado has been 11,000,000 acre-feet, so that, allowing nothing for evaporation, the Sink would be filled to the sea level in about nine years and to the 30-ft. contour in about twelve years. The enormous surface evaporation of 6 to 8 ft. vertical depth per year, over a gradually increasing area, and the seasonal and yearly fluctuations in river flow, as well as the possible effects on evaporation of the increasing area of water and the storage capacity of the dry alluvial deposit, would all have to be reckoned with in estimating the length of time that would actually be required to fill the whole basin. Practically all of the settlements in the Imperial Valley are only 100 ft. below sea level, so the basin would have

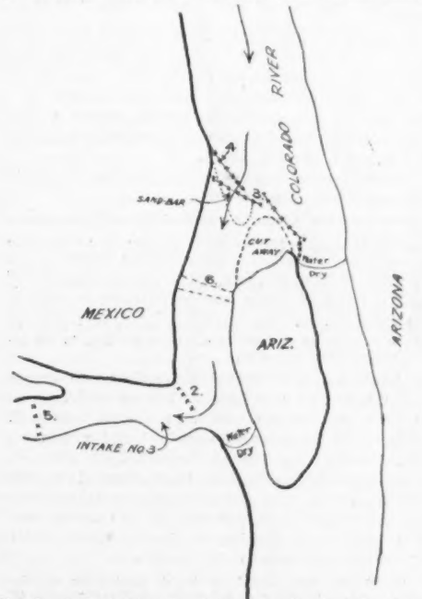


Fig. 3. Sketch Showing Efforts to Control Break of Colorado River Through Imperial Canal into Salton Basin at Intake No. 3.
(Reproduced from article by Edwin Duryea, Jr., in "Out West" for January, 1906.)

to fill to a depth of 150 before they would be reached. It is scarcely conceivable that a great corporation like the Southern Pacific will fail to control the river before the water acquires any such depth. It is reported, but we suspect on no very certain basis, that the results of the diversion of the river into Salton Sink has already cost the company a half million dollars.

*From Water Supply and Irrigation Paper 133, Progress of Stream Measurements for 1904, Part X., Colorado River and the Great Drainage Basin, Washington, D. C.; U. S. Geological Survey.

As can readily be understood, the most serious immediate danger to the Imperial Valley is that before the river is controlled the new channels into the Salton Sink will have been eroded to such a depth as to make irrigation from them by gravity impossible.

The completion of the Yuma dam on the Colorado River, above Yuma, Ariz., will, of course, affect the flood flow of that river, but the Gila comes in below the dam, and will therefore be unaffected by it.

Since the foregoing account was put in type there has come to our attention an article in "Out West" for January, by Mr. Edwin Duryea, Jr., M. Am. Soc. C. E., of San Francisco. As "an engineering representative of some of the interests injured by waters wasted through the canal," Mr. Duryea made a number of visits to the intakes during 1905, beginning in February, and also a trip through the Imperial Valley and down to Volcano Lake. We reproduce herewith two sketch maps accompanying Mr. Duryea's article: Fig. 1 showing the several intakes and Fig. 2 indicating six attempts to control the river at the lower intake, since it broke through into the Imperial Valley.

From Mr. Duryea's article it appears that two intakes, only a quarter mile apart, were first constructed, one on each side of the boundary, and that neither of these was provided with headgates. Mr. Duryea states that in the light silt of the Colorado delta "headgates are necessary to an unusual degree," and that prior to the construction of Intakes 1 and 2 (Fig. 2) wooden headworks, said to have cost $15,000, were built just above the California boundary, where they "are still to be seen." It is said that they are 5 ft. too high for use during low water, and that they have never been used.

A thousand feet or so above Intake 1 is located the only surface rock, and the only known solid foundation, "except at great depths," between this point and the Gulf. Mr. Duryea states that

> This is the only location which should have been considered for controlling-works and they should have been built here precedent to allowing the water to enter the canal.

A contract for concrete and steel headgates [mentioned above] to be located here has been let, but it was rumored, at the time Mr. Duryea wrote, that the location might be changed to a "short distance down the canal, where a firm foundation is said to have been uncovered by the late flood" [Nov. 29, 1905].

Intake 3 was dredged, Mr. Duryea states, in October, 1904. He states:

> As at the other intakes, no controlling-works were even attempted.
>
> No *added danger* [italics ours] seemed to be incurred by this third intake, as the other two had already passed three flood-seasons safely. The ground at the first two is slightly better than at the third, but the difference is slight and nothing better than unstable silt is found at any of the three sites. Though this was seemingly not then recognized, without controlling-works they were all alike a menace to the safety of the canal and to all interests along and below it.

A bank was constructed some time ago across Intake 1, but no provision had been made, up to the time Mr. Duryea wrote, to control Intake 2, which he considers as an oversight and a menace.

Mr. Duryea first visited the canal on Feb. 14, 1905. His measurements then showed nearly 2,500 cu. ft. per sec. going down the canal, of a total river flow of 30,000 sec. ft. No water was being used for irrigation at the time. Immediately after this visit to the intakes

> the Canal Co. was urged to build head-gates at the intakes. They would not acknowledge the necessity of this, however, and wished to put their controlling works several miles down the canal and shunt the water off to the Padrones River. I am told they did make an attempt to control the flood in March by a pile and timber construction near "1" (Fig. 2), and that the structure washed out just before it was closed. Five other attempts have since been made, the sixth failing in the flood of Nov. 29. * * * it was not until June, when the Southern Pacific R. R. Co. secured control of the canal company, that the first effort was made at the intakes.

At the time of his visit in February, 1905, Mr. Duryea reported that the flow through the canal could be controlled by an expenditure of less than $10,000. At this time Mr. Duryea informed Mr. William Hood, Chief Engineer of the Southern Pacific, of the danger that the Colorado would leave its bed for the canal and the Sink, but his "warning was not regarded seriously."

The first effort to control the flow from the river to the Sink has just been mentioned. Of the five other attempts (see Fig. 3) Mr. Duryea says:

> The second attempt at controlling the flow into the canal was at "2" [Fig. 3] in June. The next, in July, was at "3," and this was followed by one, not carried very far, at "4." The fifth effort was at "5." The sixth, the only one prosecuted with energy and the one which failed during the great flood of Nov. 29, was at "6." The flood covered the work entirely before it was completed, the rise having been about 13 ft. in a day. The head of the island was washed away by it, making the difficulties of renewing the work at this point very great.

In the first five attempts, "one or more rows of piles were driven and then filled in or banked up with brush." In the sixth attempt "the brush was applied in the form of mats."

The responsibility for the present menace to the Salton Basin is placed in sweeping terms by Mr. Duryea on the canal company, which, it appears, attempted to build its works before sufficient capital had been secured and took enormous risks in omitting headworks, contrary to all engineering principles. The risks in this case, obviously, were all the greater because the results may involve great public interests.

Some interesting computations regarding the time required to flood the irrigated lands and also to fill the whole basin are given by Mr. Duryea, but these are admittedly on insufficient data. He concludes that the evaporation, great as it is, cannot be relied on to offset the uncontrolled rise of water until "many of the reclaimed lands are flooded," but with an average rise of 10 ft. per year, which he apparently considers a high estimate, ten years would be required for the water to reach these lands. Mr. Duryea believes "it is practically certain the canal will be successfully controlled before even the lowest reclaimed lands are reached by the rising sea." The "real and near" menace is that the floods will erode the silt bed of the Imperial canal "so deep that its waters may sink too far below the level of the surrounding country to allow of their practicable use for irrigation."

A few additional items, of general interest, may be taken from Mr. Duryea's article: Indio (see map) is about 135 miles from Los Angeles. Before the river began pouring in the water in the Salton Sink was only a few inches deep. The "irrigated crop-bearing land" in the Imperial Valley has an area of 110,000 acres and supports a population of about 10,000. Other estimates, we may add, place the population at from 6,000 to 8,000.

PERFORMANCE OF LARGE ELECTRIC LOCOMOTIVES AND A LARGE STEAM LOCOMOTIVE.

The Baltimore & Ohio Ry. owns and operates two types of motive-power unit which are not duplicated in railway service elsewhere. The latest of these is the monster locomotive of Mallet articulated type, which was exhibited at the Louisiana Purchase Exposition. This engine was put into regular service after the exposition closed, and at the present time the experience of a full year's operation is available. About a dozen years ago, when preparing to commence operation over a new terminal approach to the city of Baltimore, Md., comprising about two miles of tunnel, the railway ordered from the General Electric Co. several large electric locomotives (direct-current), capable of hauling heavy passenger and freight trains over this terminal line, which, by the way, has grades up to 1.5%. These machines weigh 98 tons each; they are fitted for operation only in single units. Three years ago this equipment was supplemented by two 160-ton multiple-unit electric locomotives, each consisting of two 80-ton sections, which are employed in the same work as the earlier ones. Both the old and the new electric locomotives are quite comparable in size and service with large steam locomotives. The service of these electric locomotives is not unlike that of the Mallet, which is engaged in mountain-helper work; moreover, both of them do work similar to that performed by many locomotives of more familiar type throughout the country. The operating results of the Mallet and the electric locomotives are therefore of unusual interest, both as regards traffic movement and as regards cost of working.

The first compilation and publication of such results is contained in a paper read last week (Feb. 16) before the New York Railroad Club by Mr. J. E. Muhlfeld, General Superintendent of Motive Power of the Baltimore & Ohio Ry., under the title "Large Electric and Steam Locomotives." The principal parts of this paper are summarized in the following abstract, together with some notes on the discussion of the paper at the meeting mentioned.

DIRECT-CURRENT ELECTRIC LOCOMOTIVES

Brief descriptions of the electric locomotives may be found in Engineering News Nov. 29, 1894, p. 450, and Aug. 27, 1903, p. 185. The weights and some other data are noted below. The locomotives are supplied with current at 625 volts by a third-rail system, fed in parallel through booster stations and a storage battery by a power station which generates current at 560 volts.

The Baltimore & Ohio Ry. now has in its service six electric locomotives. Nos. 1, 2 and 3, each having a total weight of 196,000 lbs. carried on four pairs of driver wheels, and No. 4, a small switching locomotive, have all been in service for the past 10 years.

Nos. 5-6 and 7-8, put into service about September, 1903, are specially designed freight train helping locomotives, each having a total weight in working order of 160 tons (80 tons per section), distributed over 16 driver wheels (8 per section), with a total wheel base of 44 ft. 2¾ ins., or two 14 ft. 6¾ in. rigid wheel bases. [The following refers to these later locomotives only.]

The driver wheels are 42 ins. in diameter, each pair being geared to a 200-HP. 625-volt motor, with ratio of gearing 81 to 19, providing for a total tractive effort at full working load on 8 motors of 70,000 lbs. and at starting of 80,000 lbs., assuming 25% tractive coefficient, giving a nominal rating of 1,600 HP. The free running speed of these locomotives is about 20 miles per hour.

On level track, with good current, rail and weather conditions, they are capable of starting and accelerating a train weighing 3,000 tons with a current consumption of 2,200 amperes, which consumption, when speed increases to about 10 miles per hour, reduces to about 900 amperes. On a 1% grade these locomotives, under similar conditions, will move a train weighing 1,400 tons with a current consumption of 2,200 amperes, which consumption, when speed increases to about 10 miles per hour, reduces to about 1,600 amperes.

These locomotives handle eastbound through freight steam locomotives and trains at Baltimore, Md., from Camden Yard to Waverly, a distance of a little over 3.4 miles (3.3 miles loaded), returning light. This distance includes seven curves ranging from 5° to 11°; seven tunnels from 400 ft. to 7,000 ft. in length, and gradients about as follows: 9,000 ft., 1% grade; 2,000 ft., 1.4%; 2,500 ft., 1.5%; 4,500 ft., 0.8%.

During the past one year's service the combined mileage of these two electric locomotives has been 121,015 miles, or an average of 5,042 miles per month per locomotive, computed on the basis of 3.7 miles allowed per trip. The proportion of light and loaded mileage was half and half; about 200 miles per month per locomotive was in passenger helper service.

Considering $1.25 per net ton as a base cost for fuel delivered at the power plant, the average total operating and maintenance expenses during the year for generating the current; the labor and material for the locomotive electrical and mechanical repairs; the engineer's wages; wiping, hostlering, inspecting, oiling and dispatching; lubricating and miscellaneous supplies, was approximately 34.50 per 100 miles run per locomotive. Of this amount the average cost of labor and material applied to each locomotive for the running and shop repairs, would be $3.20 for the electrical, and $2.90 for the mechanical, making a total average cost of $6.10 per 100 miles run for the electrical and mechanical repairs.

The above figures do not take into consideration interest, depreciation, taxes nor insurance on the investment, nor do they include the expenses incident to the maintenance of such equipment as battery, feeders, third rail, bonding wires, insulation, safety cut-out switches, extra motors, etc., which is not required for steam locomotive operation. The wages for the conductor, or second man on the locomotive, have also been omitted.

During their service considerable difficulty has been experienced with the shoes used for collecting the current from the surface third rail; the loosening, wear and breakage of pinions and breakage of gears which transmit the power from the motors to the driver axles; the lubrication, heating and wear at the armature bearings; the flange and tread wear of driver wheel tire; derailments; stalling and breaking in two of freight trains due to slipping of driver wheels, more especially with wet rail when the tires of drivers connected in series are not of exact diameters; and miscellaneous renewals and shop repairs. The driver wheel tires which when new were 2⅞ ins. thick, are now 1¾ ins. thick, showing only 7,500 miles run per $\frac{1}{16}$ in. metal removed at tread, and will

have to be renewed a few months. [One section has since had tires renewed, as they had reached the minimum thickness of 1 9/16 ins.]

MALLET DUPLEX COMPOUND STEAM LOCOMOTIVE.

This monster locomotive, described and illustrated in Engineering News of June 30, 1904, p. 605, was designed to facilitate the movement of traffic over a heavy-grade division. It was designed jointly by the railway company and the American Locomotive Co., of Schenectady, N. Y., who built it; was completed in April, 1904; was exhibited at St. Louis, and was put into service on Jan. 6, 1905, on the Connellsville Division. It is the first articulated locomotive of the Mallet type in this country. It has six driving axles (no idle wheels) arranged in two trucks of three axles each, the rear being the high-pressure truck and the forward the low-pressure truck. It is the heaviest locomotive in the world, and has the largest boiler.

The total weight of 334,500 lbs. for the engine in working order is all carried on the driver wheels, which are 57 ins. in diameter. Including the tender, the total weight is 479,500 lbs., or about 193,500 lbs. less than the combined total weight of two of the Consolidation locomotives that are used for through freight service over this same mountain district. While the draw bar pull behind the tender of two of the Consolidation locomotives is about 79,400 lbs., the draw bar pull of the "2400" is about 74,000 lbs. when working compound, and 84,000 lbs. when working simple. The weight of train that can be taken up the mountain by two of the Consolidation locomotives is about 2,025 tons contained in loaded steel cars of 100,000 lbs. capacity. The weight of train that the "2400" and one of the Consolidation locomotives can take up the grade is about 3,210 tons, contained in similar cars. The above figures are based on the locomotives operating at a speed of 10 miles per hour under fair coal and weather conditions, and with the "2400" working in compound gear.

The total elevation from Connellsville to Rockwood is 931 ft., the ruling grade between Confluence and Fort Hill being 1%, and the total distance 43.4 miles. In through freight service, from Connellsville to Rockwood, the "2400," singly, has moved, in 36 steel cars, 1,668 tons of lading, and 702 tons of cars, or a total of 2,370 tons in the cars. Adding the weight in working order of the locomotive and averaging the weight of the tender loaded with coal and water at 225 tons, it would make the total weight of the train, including locomotive and tender, 2,504 tons, about 64.3% of which was paying load. The actual running time was four hours, making an average speed of 10½ miles per hour. When handling this tonnage over the hardest pulls and around 8° 30' curvature, as high a rate of speed was maintained as with through freight trains of 1,200 tons total, when handled by Consolidation locomotives. Had this same train of cars been hauled by the standard Consolidation type locomotive, it would have required the maximum hauling capacity of two locomotives to have handled it at the same rate of speed, and the average weight of the motive power would have been 304 tons, making the total tonnage of the train 2,674 tons, about 62.4% of which would have been paying load.

When helping trains consisting of a Consolidation pulling-locomotive having tractive power of 39,700 lbs., with 40 cars consisting of about 2,400 tons, weight of lading and cars, the "2400" has pushed 36 of the 40 cars in the train on 3° and 4° curvature and 1% grade, making an average speed of about 4½ miles per hour; and has pushed the entire train and pulling locomotive, weighing about 2,550 tons, when the pulling locomotive was shut off, at a speed of 2 miles per hour, and maintained the working steam pressure and the normal water level for a distance of one-half mile on the same curvature and grade, which performance could have been continued.

The performance of this locomotive for the one year period, Jan. 6, 1905, to Jan. 5, 1906, both inclusive, is as follows:

Total locomotive mileage (computed on basis of six miles per hour when locomotive is in helper service, and straight mileage allowed when locomotive is handling through freight trains)	44,976 miles*
Miles run per ton of 2,000 lbs. Run-of-Mine (3.0 to 40% volatile) bituminous coal used.	9.26
Gallons of water used per 100 miles run	15,207
Pounds of water used per pound of coal consumed, at temperature of feed water	5.870
Miles run per pint of engine oil	145
Miles run per pint of valve oil	200
Miles run per pound of crank pin grease	294
Miles run per ton of sand used	485
Cost for labor and material for repairs, per 100 miles run	$3.16

The average total operating and maintenance expenses during the year for fuel, water, labor and material for the locomotive repairs, engineer's and fireman's wages, wiping, hostlering, washing boiler, inspecting and dispatching, lubrication and miscellaneous supplies, was approximately $24.50 per 100 miles run. To this figure can be added an allowance on account of general repairs and renewals to locomotive, mileage credited but not actually run, difference in cost of fuel delivered at power plant and on locomotive tender, and for the maintenance of fuel and water supply plants, and there will still be a large margin in favor of the steam as compared with electric locomotive performance, under fairly similar conditions.

*The actual mileage is probably below this. A comparison for one month indicates that the helper mileage credited by the above computation is too high.

During this period the locomotive was used for pushing freight trains up mountain grades between Rockwood, Pa., and Sand Patch, Pa., a distance of 16½ miles, and for hauling through freight trains between Connellsville and Rockwood, a distance of 43.4 miles. During the last six months of its year's service, Aug. 7, 1905, to Jan. 6, 1905, both inclusive, the locomotive was out of service 11 days on which no mileage was made, on account of boiler washing, staybolt tests, repairs, etc., due to ordinary wear and tear, or about 6% of its time unavailable for Transportation Department work. At Rockwood, the station out of which the locomotive operates when it is in helper service, there have been no facilities, except an ash pit to enable the cleaning or drawing of fires, and water service which permits the rinsing out or filling up of the boiler. The locomotive remains in service out of this point for a two or more weeks' period, and is then taken to Connellsville for washout, staybolt test and the necessary inspection and running repair work.

Allowing for fire-box and boiler tube renewals, heavy machinery repairs, etc., we estimate, from the last year's performance, that at the end of ten years the shop charges for working repairs will have averaged not to exceed 9 cts. per mile run.

When operating over combination level and mountain divisions, No. 2400 will consume less coal per ton per mile than the various types of simple Consolidation locomotives now in the service, and when operated on a comparatively level line it consumed materially less coal per ton mile. On the mountainous part of the division, the fuel consumption per ton mile is more favorable than for the simple Consolidation locomotives, but not to such a great extent as when working on the more level portions of the division.

The general condition of the machinery and boiler on Jan. 6, 1906, after 12 months' service, was as follows: Treads of tire show even wear amounting to 3/16 in., or about 1/64 in. per month; tires calipered uniform in diameter. All parts of the Walschaert gear were in good condition, the total lost motion between the main driver wheel axles and the piston and slide valves, as measured at the valve stems, with the reverse bar in full forward position, averaged 3/64 in. for the low-pressure and slightly less for the high-pressure engines and for all engines in full back-up gear. The boiler, which carries a working pressure of 235 lbs. indicated, was in good condition, and there has been no evidence of weakness or any trouble due to staying, leaky seams, leaky or broken staybolts or leaky rivets. The staybolts are of the ordinary straight type 1 in. in diameter, spaced 3¾ ins., with tell-tale holes drilled at the outer end. The fire-box was in good condition, and there has been no indication of leakage, except at the furnace door ring, where two defective rivets were replaced by countersunk head patch bolts. The boiler tubes were good for another month's service, and there was but one flue plugged, which was due to its collapsing about 8 ft. from the front tube sheet. The engine was put into the shop on Jan. 24, 1906, and is now again in service. Its shop repairs cost (estimated) $700-$750. Two broken staybolts were found.

From the performance up to the present date if has been found that the following features embodied in the design of this locomotive have given entirely satisfactory results, with respect to design, maintenance and operation: The flexible joints to the high and low pressure cylinder, receiver and exhaust pipes. Articulated frame. Intercepting, reducing and emergency valve and intermediate chamber system of compounding and simpling. Combination hand and power reversing gear. Walschaert motion gear. High pressure piston and low pressure double ported slide valves. High and low pressure cylinder packing. Method of securing high pressure cylinders to boiler. Single disc main throttle valve. Driver, crank pin and other bearings. Injectors and water-works. Lubrication of valves, cylinders and bearings. Tracking and riding qualities, going forward or backward around maximum curvature, and when pushing, pulling or braking trains or running light.

There has been no trouble on account of priming, and the results accomplished through the distribution of the work over four instead of two main crank pins and auxiliary parts have been markedly satisfactory.

The performance of the boiler, fire-box, boiler tubes and stays, with 235 lbs. pressure, has demonstrated that it is economical and entirely practicable to operate well-designed and constructed locomotive types of boiler under severe weather, water, fuel and handling conditions, with from 200 to 250 lbs. boiler pressure. While the boiler tubes are 2¼ ins. in diameter and 21 ft. in length, there has, with ordinary attention, been practically no difficulty on account of leaky or stopped-up boiler tubes, and the steaming has been at all times free, and such as would enable the locomotive to develop the maximum tractive power under the most severe operating conditions.

While it has been noted that quite a number of changes in minor details would be desirable, should other locomotives of this type be constructed, still, when taken as a whole, the design, construction and operation in general can be considered as efficient and economical. From a transportation standpoint, locomotive No. 2,400 has been performing the service of two standard Consolidation locomotives, when used as a helper, and when handling through freight trains.

In addition to giving the above-quoted operating results, Mr. Muhlfeld, in his paper, offers a list of essentials for electric locomotives. These specifications are remarkable because they point clearly to alternating-current engines. Without taking space to quote the list in full, we may note its principal clauses. In mechanical construction an electric locomotive should be fireproof; should be able to be replaced in case of derailment by ordinary methods, without necessity for a power crane; should be composed of two or more interchangeable sections, equipped so that they may be operated jointly from a single section or independently, and from either end; should have all its weight on drivers; should have a short rigid and long flexible wheel-base, without excessive end-play in bearings; should have minimum weight between track and springs; should have a high center of gravity; should have no armatures on driver axles; should not employ gearing. Electrically, the requirements are: Capacity for 100% overload during 5 mins. and 50% overload during 1 hr.; ability to develop full power at all speeds; uniform increase or decrease in drawbar-pull, hence no sudden transition in connections as from series to multiple; automatic provision for electric braking and for return of energy in braking and coasting; such connection of motors as will eliminate independent revolution of drivers (which often occurs in series connection); a high-potential aerial line-conductor system, low in first cost and maintenance, with full protection against weather, lightning, etc., to ensure continuous operation under all conditions; the conservative use of battery storage; the elimination of electrolytic action.

DISCUSSION.

The author's favorable view of boiler pressures exceeding 200 lbs. per sq. in. brought a dissenting opinion from Mr. F. F. Gaines (Philadelphia & Reading Ry.), who holds that these high pressures will probably not prove economical in the long run. The life of the firebox is something like inversely proportional to the boiler pressure. The increased deterioration with pressures over 200 lbs. may not be apparent in the early years of life of the boiler, but the failure is very rapid when it once begins. Mr. F. J. Cole (American Locomotive Co.) reported, from observation of the large Mallet engine at work, that it rides curves remarkably well and is very easily handled. At one end of the line is a Y for turning the locomotive, which has 23° curves; the engine takes these curves easily, without grinding or uneasiness. The power reverse gear greatly facilitates the work of handling the locomotive. No difficulty in firing is reported, and it appears that the fireman is not taxed appreciably more than on an ordinary heavy locomotive. It is true, of course, that in helper service (slow speed) the power developed by the engine would not be great—less than 1,000 HP.—and the engine probably never averages over 1,500 HP. in road work, an output which is often reached in ordinary locomotives; this serves to explain the absence of difficulty in firing. A noteworthy fact is the reported absence of trouble with the long flues. Absence of unusual flange wear is also to be noted, as it indicates that trucks are not necessary; the low average speed, however, would operate to lessen flange wear. The absence of trucks or idle wheels makes the driver weight of this locomotive 100% of the total engine weight. In other types of locomotive the driver weight is the following proportion of the total: Atlantic type, 51%; Pacific type, 61%; 10-wheel, 75%; Consolidation, 89%. It appears that these ratios bear a consistent relation to the normal speed of the

respective types, which relation is also found in the Mallet, a slow-speed engine.

Mr. H. H. Vaughan (Canadian Pacific) takes the paper to demonstrate that there is a large future before the Mallet type of locomotive in heavy-grade service, at least for pusher service, and perhaps even more generally for freight work on mountain grades. The expected cost of 9 cts. per mile for the maintenance of the Mallet locomotive, Mr. Vaughan thought, appears too low for a tractive effort of 72,000 lbs., but it is probably difficult to make a reasonably close estimate at the present time. The repair costs would naturally increase steadily for five or six years, by which time a permanent annual maintenance charge will be reached. Basing on the repair costs for other heavy types of locomotive, the final maintenance charge for the Mallet should prove to be much higher than 9 cts. It appears from experience that the maintenance costs of locomotives of different types are fairly well proportioned to either the weight of the locomotive or the maximum drawbar pull; that is to say, the maintenance cost per ton mile is about the same for all types, and it may be noted as a curious fact that it is about the same in the case of ordinary freight cars. The maintenance cost given by Mr. Muhlfeld for the electric locomotive will, Mr. Vaughan thinks, also prove to be very much higher when longer service and more extensive experience with such engines is available.

Concerning the electric locomotives of the Baltimore & Ohio, Mr. Vaughan brought out the statement from Mr. Muhlfeld that his figures of cost and his remarks on experience refer only to the last two locomotives built for that road, namely, the 160-ton two-section machines put into service in 1903. Mr. Muhlfeld added the statement that the earlier electric locomotives furnished his road were perhaps more satisfactory all around than the last.

The powering of the electric locomotives at about 10 HP. per ton is quite low, in Mr. Vaughan's opinion, and future electric locomotives will doubtless greatly exceed this figure. The Baltimore & Ohio locomotives were probably designed "comfortably," without the pressure of any limiting conditions which would lead to high capacity per ton. With higher powering, the electric locomotives may show a clear advantage over steam locomotives in average speed over rough profiles.

The direct discussion of the comparison of steam and electric locomotives was introduced by Mr. C. F. Scott (Westinghouse Electric & Mfg. Co.) with a defense of the Baltimore & Ohio electric machines. These are employed in a service (tunnel haulage) which steam locomotives could not be used for; they were designed and the electric plant laid out in the very early days of heavy electric traction. The comparison made in the paper is therefore between a pioneer, old-fashioned electric traction system and a new and unique type of steam locomotive, the first of its kind in this country. Concerning the author's specified requirements of electric locomotives, it appears that there are some unique features called for, both in the mechanical and in the electrical construction. The elimination of pilot wheels, the high center of gravity, armature not carried on axle, and the other mechanical requirements, are all embodied in the designs for the locomotive to be built by the Westinghouse company for the New York, New Haven & Hartford Ry. Altogether, there is a striking agreement between the two, as will doubtless appear at the next meeting of the club, when Mr. B. G. Lamme will present a description of the New Haven locomotive. The electric specifications of Mr. Muhlfeld are remarkable, in that all of them point toward the alternating current and away from the direct current system of traction. The alternating current realizes the change of connection for varying speed without altering the motor connections; eliminates the danger of the slipping of wheels due to series connection, because the motors can be kept always in parallel; permits the return of energy to the line in a practical way and at all speeds, and does away with the danger of electrolysis. In all of these points the direct-current system is defective. In relation to the third-rail, as contrasted with overhead conductor, there is no report of experience to be found in Mr. Muhlfeld's paper. Although the Baltimore terminal plant employs a third rail, Mr. Muhlfeld's specifications call for high-potential line-current and overhead conductors, and this may be taken to indicate unfavorable experience at Baltimore with the third rail; the high-potential and overhead conductor specification, of course, almost necessarily means alternating current operation. The operating costs of the electric locomotives which are given by Mr. Muhlfeld as 34½ cts. per mile are unfortunately not subdivided, except for the statement that the maintenance charges amount to 6.1 cts. Now, a large item in the operating costs is the cost of power. The generating system at Baltimore is old-fashioned, has small, old-style units, and is probably very inefficient, and the conductor system has probably high losses in addition; so that the cost of power delivered with the locomotive would be very high. If this be true, a more modern and more economical power supply plant would improve the showing of the electric locomotive as compared with the Mallet.

A more detailed defense of the electric locomotive was made by Mr. W. P. Potter (General Electric Co.). The electric locomotives at Baltimore, weighing 160 tons per two-unit section, have a greater power output and the same effective drawbar pull as the Mallet locomotive weighing 240 tons, or half again as much. The large locomotive built by the General Electric Co. for the New York Central has proved itself superior to any of the New York Central steam locomotives in speed, after it had shown itself the superior of steam locomotives in hauling capacity. Hauling power, the first object of freight locomotive design, may be increased to any extent with electric locomotives by coupling up a number of units, all controlled from a single cab. In power output the Baltimore & Ohio locomotives do not show up as well as they might, because they were designed for specific service, one-half of which was running light down grade, mainly coasting. By fitting them with forced ventilation, they could easily develop their maximum output continuously, and would then greatly exceed Mr. Muhlfeld's estimate of 10 HP. per ton.

Concerning the operating cost comparison between the electric locomotives and the large Mallet, Mr. Potter computed that by correcting the figures for the Mallet locomotive in accordance with actual figures of mileage run, as compared with mileage credited on the basis given in the paper, and by substituting the estimated future maintenance charge of 9 cts. per mile for the 3 cts. present cost, the total operating cost appears to be not lower than that of the electric locomotives, but even one or two cents higher. But Mr. Potter further predicted that the Mallet locomotive would in time show a very much higher repair cost than is at present estimated. The figure of 9 cts. per mile, or $3,500 per year on a mileage approximating 40,000, is, according to Mr. Potter, even lower than the annual maintenance cost of the average heavy locomotive of accepted types. It seems reasonable to conclude that this locomotive, which is much heavier, should have a correspondingly greater annual repair cost. [Mr. Muhlfeld, however, subsequently stated that the Baltimore & Ohio has an average annual repair cost of only $2,600 per locomotive, and the majority of its locomotives are the heavy-grade type, among them a large number of Consolidation.] The maintenance charges for the electric locomotives, Mr. Potter stated, should, on the contrary, be much lower than those given in the paper. Figures of the New York Central locomotive, which at present has completed some 35,000 miles in preliminary service, and for some other locomotives, show repair costs during periods of one to four years ranging from less than 1 to 1½ cts. per locomotive mile, and it seems proper to expect a similar performance from other suitably designed electric locomotives when properly handled. The heavy tire wear which was remarked on in the case of the Baltimore & Ohio electric locomotives is to be explained in part by the small size of the driving wheel. Computed in actual wear of metal in pounds, Mr. Potter estimates it as less than the tire wear of the Mallet locomotive by some 30% (but this computation, as well as Mr. Potter's calculation of the higher operating cost of the Mallet, was subsequently contradicted by Prof. H. W. Hibbard). The power cost, the other important factor of operating cost, should turn out to be about the same for electric and steam locomotives; in particular cases, of course, a high coal cost or high capital charges will make one or the other appear to better advantage. The power output of electric locomotives per ton will undoubtedly always exceed that of the Baltimore & Ohio engines. The New York Central locomotive, for example, has a normal output of 22 HP. per ton and 30 HP. per ton at the maximum. The construction of this locomotive, moreover, is hardly favorable to low weight, as it has the motor armatures mounted direct on the axle, and therefore it loses the benefit of the high speed which may be obtained from gears. At the same time the dead weight per axle is no higher on the New York Central locomotive than in the ordinary steam locomotive, and in the former is in perfect rotative balance, which is not the case in the latter. Gears for the drive of electric locomotives are undoubtedly out of the question. Even in motor car work to-day the limit has been reached for cast-steel gears, and recourse may have to be had to gears with a forged rim like the tire of a locomotive.

The discussion was continued by Messrs. Angus Sinclair, C. F. Street, F. M. Whyte, G. R. Henderson and others. In closing, Mr. Muhlfeld gave some additional information: The maintenance cost of all locomotives on the Baltimore & Ohio averages only $2,600 per year, and the large proportion of heavy-grade locomotives makes this figure apply almost directly to them. The maintenance cost in pusher service should not be higher than that for mountain freight service. He feels certain that the Mallet locomotive will not go beyond the figure of 9 cts. given in the paper. Little value can be attached to the low maintenance cost of the New York Central locomotive, as it has not yet gone into regular service. The conditions of tire wear on the electric locomotives are often worse than stated in the paper. One section, put into service with new tires last December, is back in the shop now (middle of February) for new tires; the tire wear is exceedingly irregular, and one of the wheels is loose on its center.

The power-plant at Baltimore is of old design and has small units. Though the intention is to replace the plant by a new one, the old plant operates satisfactorily and economically. It supplies current for lights, power in shops, etc., and its load is equalized by a storage battery; as a result it produces power at a cost of 0.7 to 0.8 ct. per KW.-hr., a figure hard to improve on, even with a modern plant. The condition of the power-plant has little bearing on the high operating cost of the electric locomotives.

EXPERTS' REPORT ON LEAKS IN THE TORRESDALE WATER TUNNEL, PHILADELPHIA.

The Torresdale tunnel of the Philadelphia filtration system does not comply with the specifications in point of water tightness, and the contractors have been overpaid some $85,000, according to a report submitted to Mayor Weaver on Feb. 16 by his committee of filtration works experts. The committee was appointed some months ago to investigate alleged defective work and over-payments on several large filtration contracts. The members of the committee are Major Cassius E. Gillette, U. S. A.; Wm. Barclay Parsons, New York City; and John D. Maclennan, Philadelphia. A lengthy earlier report, dealing with other phases of the contracts, was published in our issue of Nov. 2, 1905.

The present report is brief. Its essential points are given below. Opening with the subject of water-tightness, the experts quote from the specifications essentially as follows:

> The plans and this specification show the general arrangement and manner of constructing the work under this contract. It is the intention of the plans and specifications to produce a water-tight lining to all portions of the work.
>
> The contractor will be held responsible for the water-tightness of the whole work. If it is necessary, in addition to what is shown on the plans and described in the

specifications, to provide any other materials or labor to accomplish these purposes, he shall furnish such additional materials or labor without increased cost to the city.

It is distinctly understood that all the work shown on the plans and described in the specifications is to be built to the dimensions shown, and in the manner specified, and that any other precautions which the contractor may elect to use shall be outside of, and in addition to, what is shown and specified, and shall be executed without cost to the city.

Commenting on the foregoing clauses the experts express their conviction that more vigorous or more clear language could not have been used had the intention been "to require absolutely water-tight construction." The report then continues:

We find upon investigation that the structure is not water-tight. After having the conduit pumped out, we counted the leaks and measured their flow separately and collectively. About one-third of the measured leakage comes from 150 spurting streams, a small quantity coming from three defective weepers. The total leakage averages more than 1,500,000 gallons per day, enough to furnish a water supply for a city of 15,000 people.

Aside from a failure to make the tunnel water-tight the report declares that the specifications were not followed (1) in that the contractor was paid $9,673 for tar-paper to add to the water-tightness, which paper was "one of the 'other materials'" which the contractor should have supplied without charge; and (2) that he was paid a total of $75,591 for filling voids outside the prescribed lines of the tunnel excavation. On the latter point the specifications read:

Where rock has been excavated outside of prescribed lines, from whatever cause, the voids between the brick masonry and the sides of the excavation must be thoroughly filled with concrete, making the work water-tight. No additional compensation will be allowed for the rock removed or the concrete filling of voids.

The contractor was paid for 5,635.2 cu. yds. of concrete at $8 per yd. and 7,418.7 at $5.95 for filling outside the brickwork, making a payment of $75,591 "literally presented to the contractor."

Analyses of the water coming into the conduit through "a great many of the leaks" indicated contamination in "very few samples," and that "never more than a few hundred bacteria per c. c.—a dangerous number—and some indications of sewage contamination." As the area above and near the conduit becomes thickly populated and sewers are built the dangers of contamination through rock fissures will increase; these dangers occurring when the tunnel is not under internal pressure and when, at the same time, the ground water level is high. Such conditions being considered dangerous by the investigating commission it recommends

that the conduit be made water-tight. The best method of doing this, in our judgment, is to pump liquid cement back of the brick lining through holes drilled for this purpose. This cement will find its way into the defective work and finally seal the innumerable small leaks that now exist, and which can be closed in no other manner. Unless cavities are found back of the lining larger than any the borings have yet struck, the cost, while it will probably be large, will not be enough to justify abandoning the conduit.

The total payments on account of this tunnel contract have been about $1,321,000. The tunnel was described in detail in Engineering News for Dec. 1, 1904.

THE OFFICIAL REPORTS ON THE PLANS FOR THE PANAMA CANAL.

The majority and minority reports of the Board of Consulting Engineers for the Panama Canal were made public on Feb. 19. Below we present the most important parts of President Roosevelt's message to Congress transmitting the report, of Secretary Taft's recommendation and of the report of the Isthmian Canal Commission, all of which documents, it will be seen, unhesitatingly approve the lock canal project as presented in the minority report.

On pp. 202 et. seq. of this issue will be found a summary of the Consulting Board's report and an abstract of the majority report recommending a sea-level canal. The minority report, favoring a lock canal, we postpone to our next issue.

President Roosevelt's Message.

To the Senate and House of Representatives:

I submit herewith the letter of the Secretary of War transmitting the report of the Board of Consulting Engineers on the Panama Canal, and the report of the Isthmian Canal Commission thereon, together with a letter written to the Chairman of the Isthmian Canal Commission by Chief Engineer Stevens. The Secretary of War recommends a lock canal pursuant to the minority of the Board of Consulting Engineers and of the majority of the Canal Commission. After careful study of the papers submitted and full and exhaustive consideration of the whole subject I concur in this recommendation.

In my judgment the very able argument of the majority of the Board of Consulting Engineers is vitiated by their failure to pay proper heed to the lessons taught by the construction and operation of the Soo canal.

A careful study of the reports seems to establish a strong probability that the following are the facts: The sea level canal would be slightly less exposed to danger in case of war; the running expenses, apart from the heavy cost of interest on the amount employed to build it, would be less; and for small ships the time of transit would probably be less. On the other hand, the lock canal at a level of 85 ft. or thereabouts would not cost much more than half as much to build and could be built in about half the time, while there would be very much less risk connected with building it, and for large ships the transit would be quicker; while, taking into account the interest on the amount saved in building, the actual cost of maintenance would be less. After being built, it would be easier to enlarge the lock canal than the sea level canal.

The law now on our statute books seems to contemplate a lock canal. In my judgment a lock canal is herein recommended as advisable. If the Congress directs that a sea-level canal be constructed, its direction will of course be carried out. Otherwise the canal will be built on substantially the plan for a lock canal outlined in the accompanying papers, such changes being made of course as may be found actually necessary.

THEODORE ROOSEVELT.

The White House, Feb. 19, 1906.

Secretary Taft's Report to the President.

War Department, Washington, Feb. 19, 1906.

The President.

Sir: I have the honor to forward, herewith, the report of the Board of Consulting Engineers for the Panama Canal, convened by your order of June 24, 1905, with the views of the Isthmian Canal Commission and of the Chief Engineer of the Canal.

* * * * * * *

The high level canal more fully meets the requirements of Congress.

The majority of the Board makes objection that locks are unsafe for the passage of the great seagoing vessels contemplated by the act, due to the disastrous consequences that might result if the gates are injured by vessels entering; that the lifts proposed are beyond the limit of prudent design for safe operation and administrative efficiency; that locks delay transit.

Lock navigation is not an experiment, all the locks are duplicated, thereby minimizing such dangers, and experience shows that with proper appliances and regulations the dangers are more imaginary than real. The locks proposed have lifts of about 30 ft., or less than those heretofore advocated by engineers of such high standing that the objection is believed to be not well founded. The delays due to lockages are more than offset by the greater speed at which vessels can safely navigate the lakes formed by the dam than is possible in the sea level canal, and the arguments on this point in the minority report seem to me to be more weighty.

The sea level canal gives tortuous navigation for the greater distance through a comparatively narrow gorge in which the largest vessels cannot proceed under full headway, pass without risk, or turn about. The high level canal, for the greater distance, gives practically lake navigation in which vessels can proceed at full speed along straight courses, pass each other without delays or risks, and can turn about, if necessary.

The high level canal has the additional advantage of "greater safety for ships and less danger of interruption to traffic, by reason of its wider, deeper and straighter channels."

The estimated cost of $247,021,000 for the sea level canal and $130,705,200 for the 85-ft. level canal, a difference of $107,000,000. The Isthmian Canal Commission and the Chief Engineer regard the estimate for the sea level canal as too low by at least $25,000,000, for reasons stated in their reports. The advantage of less cost is greatly in favor of the 85-ft. level canal.

The estimated time for completing the sea level canal is stated by the majority of the Board as from 12 to 13 years, by the Isthmian Canal Commission and the Chief Engineer, from 15 to 20 years. The minority report estimates the time for completing the high level canal at 8½ years, and this is regarded as conservative by the other competent authorities.

The advantage in "practical speed of construction" is in favor of the high level canal.

In view of the foregoing, I recommend the adoption of the type of canal proposed by the minority of the Board of Consulting Engineers, except so far as relates to the location of the locks at Sosa Hill.

The great objection to the locks at Sosa Hill is the possibility of their destruction by the fire from an enemy's ships. If, as has been suggested to me by officers of this Department entitled to speak with authority on military subjects, these locks may be located against and behind Sosa Hill in such a way as to use the hill as a protection against such fire, then economy would lead to the retention of this lake. If, however, Sosa Hill will not afford a site with such protection, then it seems to me wiser to place the locks at Miraflores.

I ought not to close without inviting attention to the satisfactory character of the discussion of the two types of canal by the greatest engineers of the world, which insures to you and to the Congress an opportunity to consider all the arguments, pro and con, in reaching a proper conclusion.

Wm. H. Taft, Secretary of War.

Report of the Isthmian Canal Commission Approving the Report of the Minority of the Board in Favor of a Lock Canal.

Mr. Secretary.—The Isthmian Canal Commission has the honor to transmit herewith two reports which it has received from the Board of Consulting Engineers.

Before proceeding to a review of these two reports it is desirable to remove certain misapprehensions as to the meaning of the terms "canal at sea level" and "canal with locks" as defining the character of the completed waterway. In the popular mind the one means a waterway affording navigation without restriction, while the other means a waterway in which navigation is delayed and hampered by mechanical appliances, and decidedly inferior to the former. These conceptions are quite inaccurate. * * * *

In a canal with locks, artificial lakes are created in which for considerable distances the navigation is entirely unrestricted. The advantages thus gained may more than counterbalance the delay and risk in the use of locks, and it is quite conceivable that a canal with locks may be a better canal—that is, can be navigated in less time and with less risk than a canal at sea level.

SEA-LEVEL PLAN.

The cost of the canal under this plan is estimated by the majority at $247,000,000. From the nature of the case this estimate cannot be made with great precision. It is the opinion of this Commission that the unit prices adopted by the Board are, upon the whole, judicious, except in the case of rock excavation under water, which seems to us low, but is accepted here for purposes of comparison; and that otherwise the estimates are as near an approximation to the truth as can now be reached, in all except two items. These items are the excavation in Culebra Cut below elevation + 10, given as $20,242,877.50; and the completion of river diversions, regulation of rivers flowing into the canal, etc., given as $3,500,000.

The first item covers 16,194,302 cu. yds of excavation, of which 11,439,612 cu. yds. is below and the remainder above the level of the sea. The majority of the Board has adopted a uniform unit price of $1.25 per cu. yd. for the whole. This price seems fair for the portion above the level of the sea. For the portion below, it seems to the Commission that the price of rock excavation under water, $2.50 per cu. yd., should be applied here as it is in the adjacent sections of the canal by the Board. If that be done, the cost of this item will be increased $14,299,515, and adding the usual 20% for contingencies, the estimate will be increased $17,159,418.

The estimate, $3,500,000, of the cost of completing the river diversions, formation of dams across tributary streams, regulation of rivers which flow into the canal, etc., is believed to be too low.

The Cano and the Gigante are to be cut off by dams. The Trinidad will occupy the old channel of the Chagres River and the Chagres diversion. The Gatun will be cut off from the canal by the partly finished Gatun diversion, into which also will be conducted the Mindi River, which has not been gaged, but which is a stream of considerable importance. The others are to be taken into the canal. They must, however, be temporarily diverted during the excavation of the canal; and in the case of the Rio Grande this involves a tunnel seven-eighths of a mile long. In all the diversion channels together, the amount of excavation and levee building, with the necessary muck ditches and riprap levee and bank revetments, tunnels, etc., cannot be less than 10,000,000 cu. yds. The unit price will be high. The dam to close the Gigante will be about 2,800 ft. long, that to close its main tributary, the Gigantito, will be about 490 ft. long, and that to close the Cano about 820 ft. long, the height in each case being about 75 ft. above the ground, the depth to which the foundations must be sunk being unknown. A dam about 535 ft. long and 25 ft. high will be required to close a depression in the rim of one of the lakes. These and the spillways are expensive works. Their locations have never been examined by borings or exact topography, with the exception of the Gigante spillway. Their cost cannot be accurately estimated without further examinations, but under favorable circumstances can hardly be less than $1,000,000.

It is the opinion of the Commission that the sum of $3,500,000, assigned by the majority of the Board to the completion of the diversion channels, the construction of the dams and spillways, and the construction of these aprons, is inadequate, and should be increased by at

least $6,500,000, which, with the usual 20% added for contingencies, makes an increase of $7,800,000 to this item of the estimate.

If the foregoing increases be added to the $247,000,000 estimated by the majority of the Board, the cost of the sea-level canal will be found to be $272,000,000.

The time required to build the canal is estimated at twelve to thirteen years. The number of unknown factors which enter into this estimate is still greater than in the case of estimates of cost. There are two methods available for reaching a conclusion upon the subject. One is that followed by the Board, viz., to assume that the largest single piece of work—the Culebra Cut—will fix the time required, and that all other work can be completed while that is being executed, then to ascertain how many excavating machines can be employed at one time in the Culebra cut, and then assign to each machine its daily or annual working capacity, under the conditions which prevail there. There is great uncertainty about all of these elements. The number of steam shovels which can work to advantage in Culebra cut is not known, but is probably much less than the number mentioned in the report, 100; and there is no experience to show what the output of a steam shovel will be under all the extremely varying conditions which obtain there.

It is to be feared that the time required to construct a sea-level canal would be eighteen or twenty years, rather than the twelve or thirteen years estimated by the majority, even supposing that the total amount of excavation will not exceed the 231,000,000 cu. yds. estimated. To reach that amount the majority of the Board has adopted steeper slopes in the Culebra cut than any previous board or commission has adjudged applicable. It may well happen that these slopes must be reduced, and the amount of excavation thus increased. The majority of the Board has made no provision for the necessary turning-out places and widening at curves. It is not safe to estimate the time required for the construction of a sea-level canal at less than twenty years.

PLAN WITH LOCKS.

The plan recommended by the minority of the Board is a canal with locks, following in general the same location as the other, but with slight variations therefrom in Limon and Panama bays. Its controlling feature is a dam to close the valley of the Chagres at Gatun, thus creating an artificial lake of which the surface is to be 85 ft. above the sea and which is to constitute the summit level. For about half the distance navigation is entirely unrestricted, while for more than two-thirds the distance the channels are 500 ft. or more wide, and for only one-seventh the distance, including the locks, are they less than 300 ft. wide.

The cost of the canal under this plan is estimated by the minority of the Board at $139,705,200, and the time required to build it at nine years. We consider both of these estimates reasonable, subject to the remarks already made concerning unit prices.

The plan recommended by the minority of the board is of the same type as that recommended by the Commission of 1899-1901 and adopted by Congress, at least by inference, in the act approved June 28, 1902. It provides wider and deeper channels and larger locks than that plan and a different arrangement of dams, as well as a change in the Atlantic entrance, but the estimates of cost and of the time required for construction are very nearly the same. Some of the changes are of importance, but they do not seem to us to be changes of such radical character as would require further action by Congress, as in the case of a canal at sea level.

The only features of this plan which do not fall within the limits of every-day practice are the height and size of the dams and the size of the locks. No question has been raised as to the stability of the Gatun dam, and, indeed, none can be raised while there are in successful operation in this country earth dams of less cross section retaining a greater head of water. The great quantity of material available has made it possible to give this dam dimensions which are much greater than are strictly necessary. The majority of the board, however, do question the effectiveness of that dam in retaining water, expressing the fear that the subfoundation may be found so porous that seepage will be excessive. The minority point out that the material under the dam is exceptionably favorable, that for a depth of 200 ft. it is practically impervious, and that the more porous material which is found for a short distance below that depth is covered with this impervious blanket 200 ft. thick for a long distance upstream. They express the opinion, in which we concur, that there would be no appreciable seepage under the dam.

The locks are larger than any which have heretofore been built, and the majority of the Board express the opinion that they are beyond the limit of prudent design. As a matter of fact, larger locks have been designed with the greatest prudence and with mathematical certainty. It can no more be said of lock building that it has reached the limit of judicious construction than of ship or bridge building or any other branch of engineering construction. A modern bridge of long span is a safer structure than the short span bridge of former days, because of better knowledge of the materials and improved methods of uniting them. So the proposed locks can be made safer than the Poe lock at the Sault, because they are designed after nine years of practical experience with that lock, an experience which shows it to be a safe place for a vessel.

It is our opinion that the entire feasibility of constructing the canal under the plan proposed by the minority of the Board cannot be successfully questioned.

RELATIVE EFFICIENCY OF COMPLETED CANALS.

The majority of the Board express the opinion that the canal at sea level is the only one giving reasonable assurance of safe and uninterrupted navigation, and question the safety of large vessels in passing locks.

The most important ship canal in the world is that at the Sault Ste. Marie, at the outlet of Lake Superior. The tonnage which it carries per annum is about three times that carried by the Suez Canal, and is greater than the aggregate tonnage of the Suez, Manchester, Kiel, and Amsterdam canals combined, although navigation is suspended several months each year by ice. One of its locks is the largest in existence, and during the season of navigation this lock alone carries three times the tonnage per month that the Suez Canal carries. It has been in successful operation since 1896, and has carried with ease and safety the largest vessels on the Great Lakes, some of them measuring 560 ft. in length with 56 ft. beam. The navigation interest has no fear of this lock. That interest is growing with marvelous rapidity, and is clamoring for deeper channels between the lakes, so that larger vessels may be used and larger locks built. No engineer who is familiar with this lock has any misgiving about its safety, or about the entire feasibility of building larger locks which shall be equally safe.

The majority of the Board have attempted to belittle this experience. They attach importance to the fact that navigation at the Sault is closed by ice for several months each year, at which time the locks can be pumped out and repaired, not stopping to consider that at Panama there are two sets of locks, one of which can be pumped out and repaired at any part of the year. They point to the three accidents which have occurred to the locks within the last nine years, and make certain speculations as to how near these were to being serious and what would have happened if the lift had been as great as that proposed for Panama, omitting to note that during the same period the open channels below were completely blocked three times, besides being partially blocked at other times, by the sinking of vessels. We cannot concur in the opinion that a lock properly constructed and managed is in any sense a menace to the safety of vessels. Practical experience has demonstrated the contrary beyond dispute.

The majority of the Board claim that locks limit the traffic capacity of the canal, that lockages perhaps cannot exceed 10 per day for each lock, or 20 per day for the pair. The minority point to the experience at the Sault, which shows that this estimate is not in accord with American practice, and they show that with the double flight of locks proposed, a traffic of at least 80,000,000 tons per annum can be accommodated. Additional locks may be built hereafter if needed.

The majority in one place express the opinion that the canal at sea level "will endure for all time," and in another give weight to "the comparative ease and economy of enlarging the prism of the sea-level canal to accommodate any additional demands of the future." We estimate that to widen the sea-level canal 100 ft. without deepening it will cost at least $87,000,000. To deepen it involves excavation under water throughout its length. The canal with locks may be deepened easily and cheaply by simply raising the crests of the spillways and the height of the locks.

The majority express the opinion that the cost of operating and maintaining a sea-level canal will be very much less than that for a canal with locks; and using the figures of the Commission of 1899-1901, they give the cost of operating and maintaining the locks at about $525,000 per annum. That estimate is probably as near an approximation to the truth as can now be given. The canal at sea level will require more dredging than the other, and it has one lock to be maintained. It must also be furnished with turn-out places and attendance there. A reasonable allowance for these expenses is $225,000, leaving $300,000 per annum as the apparent advantage in operating expenses of the sea-level canal. Against this is to be placed the interest on the additional investment. If the canal at sea level will cost $132,000,000 more than the canal with locks, as we believe it will, the interest on that sum is an additional fixed charge, and at 2% amounts to $2,640,000 per annum; that is, the annual fixed charges of the canal at sea level will be $2,340,000 more than those of a canal with locks.

There is one valid argument, and one only, which can be brought against the canal with locks, and that is the difficulty of fixing the dimensions of the lock chambers to provide for the possible enlarged vessels of the future. The majority of the board propose a length of 1,000 ft., a width of 100 ft. and depth over the miter sills of 40 ft.; while the minority propose a length of 900 ft., a width of 95 ft. and 40 ft. over the miter sills. In the following table is a list giving the dimensions of 12 of the largest ships in the world and the ratio of their length and beam to their draft:

Name of steamer.	When built.	Length over all. ft.	Beam. ft.	Maximum loaded draft. ft.
Kaiser Wilhelm der Grosse...	1897	648.4	66.0	28.5
Kaiser Wilhelm II.	1902	706.5	72.0	30.5
Kronprinz Wilhelm	1901	663.3	66.0	30.0
Oceanic	1899	705.6	68.4	35.7
Celtic	1901	697.5	75.4	36.8
Cedric	1903	697.5	75.4	36.9
Baltic	1903	725.9	75.4	37.3
Deutschland	1900	687.5	67.3	31.0
Caronia	1904	680.0	72.6	35.0
Carmania	1904	680.0	72.6	35.0
Two new Cunard ships.....	1905-6	800.0	88.0	38.0

From this table it appears that the proportions suggested by the minority are more in accord with late practice than those suggested by the majority. The minority point out that the dimensions proposed by them will provide for ships having 25% more tonnage than the new Cunarders, and will permit the passage of battleships having 13 ft. greater beam than any ship now in the United Stafes Navy. Inasmuch as the new Cunarders are not yet completed, are very much larger than any other vessels in existence, and must still be regarded as experimental, it seems to us that this is looking as far into the future as is expedient. If ships too large for these locks should hereafter be developed, it will be possible to add new and larger locks to accommodate them. The total estimated cost of all the locks and approach walls in the present project, including the contingency item of 20%, is $44,425,000. They can therefore be entirely renewed for about half what it would cost to widen the sea-level canal 100 ft.

The water supply for the canal with locks as projected is sufficient to accommodate a traffic of about 50,000,000 tons annually. Should that traffic be exceeded in the future, the addition of a dam at Alhajuela will provide a supply sufficient for 100,000,000 tons. Should it be found necessary in the future to provide for the passage of a still larger tonnage, the Chagres River and its tributaries will furnish additional water.

CONCLUSIONS AND RECOMMENDATIONS.

From the foregoing it appears that the canal proposed by the minority of the Board of Consulting Engineers can be built in half the time and a little more than half the cost of the canal proposed by the majority of the Board, and that when completed it will be a better canal for the following reasons:

(1) It provides greater safety for ships and less danger of interruption to traffic by reason of its wider and deeper channels.

(2) It provides quicker passage across the Isthmus for large ships or a large traffic.

(3) It is in much less danger of damage to itself or of delays to ships from the flood waters of the Chagres and other streams.

(4) Its cost of operation and maintenance, including fixed charges, will be less by some $2,000,000 or more per annum.

(5) It can be enlarged hereafter much more easily and cheaply than can a sea-level canal.

(6) Its military defense can be effected with as little or, perhaps, less difficulty than the sea-level canal.

We recommend that the plan of the minority be adopted, subject, of course, to such changes as may be found desirable during construction.

T. P. Shonts, Chairman; Charles E. Magoon; Peter C. Hains, Brigadier-General, U. S. Army, Retired; O. H. Ernst, Colonel of Engineers; B. M. Harrod.

Admiral Mordecai T. Endicott, of the Commission, files a minority report expressing preference for a sea-level canal, chiefly on the ground that such a canal would have military advantages as compared with the lock canal.

Letter of John F. Stevens, Chief Engineer.

Washington, D. C., January 26, 1906.

Sir: In reply to your request for a statement of my views on the question of a sea-level or a high-level canal, as applicable to Panama, and my conclusions as to the relative value of each type, as discussed in the reports of the Consulting Board of Engineers—

As indicated in my letter of Dec. 19, 1905, which was written prior to the receipt or inspection by myself of any report from the Consulting Board, my judgment was and is yet in favor of a high-level canal, and it has only been strengthened by the very able presentation of the facts and deductions made therefrom in the minority report.

The minority report of the consulting board has discussed so fully the relative merit of the two types that it would seem entirely unnecessary for me to endeavor to extend the arguments.

I will, however, express my belief that some of the estimates as to the length of time and cost, as set forth by the report in favor of the sea-level type, are hardly justified. I believe that the estimated cost of the auxiliary works, such as diversion channels, dams, and spillways,

may very readily exceed by several times the amount allowed, and that the danger to the canal by the existence of such works would be much greater than apparently appreciated.

I believe the excess cost of the sea-level type, instead of being $107,000,000, as indicated in the reports, would be at least $135,000,000, and it might be very much more.

I also believe that the difference in the time required for the construction, as between the two types, will be much greater than reported, and I would not care to set a less time than eighteen or twenty years for the building of a sea-level canal, while I am firmly of the belief that the time, as shown in the minority report, for the construction of the high or 85-ft. summit level is ample.

The sum of my conclusions is, therefore, that, all things considered, the lock or high-level canal is preferable to the sea-level type, so-called, for the following reasons:

It will provide as safe and a quicker passage for ships, and therefore will be of greater capacity.

It will provide, beyond question, the best solution of the vital problem of how safely to care for the flood waters of the Chagres and other streams.

Provision is made for enlarging its capacity to almost any extent at very much less expense of time and money than can be provided for by any sea-level plan.

Its cost of operation, maintenance, and fixed charges will be very much less than any sea-level canal.

The time and cost of its construction will be not more than one-half that of a canal of the sea-level type.

The element of time might become, in case of war, actual or threatened, one of such importance that measured, not by years but by months, or even days, the entire cost of the canal would seem trivial in comparison.

Finally, even at the same cost in time and money for each type, I would favor the adoption of the high-level lock canal plan in preference to that of the proposed sea-level canal.

Very respectfully,
Jno. F. Stevens, Chief Engineer.

THE CHICAGO DRAINAGE CANAL CASE has been decided in favor of the drainage district by the U. S. Supreme Court. The suit was technically brought by the State of Missouri against the State of Illinois, but was really instituted on behalf of St. Louis against the Chicago Drainage District, which latter is composed almost wholly of the city of Chicago. St. Louis tried to prove that the sewage of Chicago would imperil its water supply. A large number of engineers, chemists and biologists were engaged by each side of the controversy, and the testimony altogether is said to rank second in volume in the records of the U. S. Supreme Court. The decision was rendered by Justice Holmes. There was no dissenting opinion.

TYPHOID FEVER AT PHILADELPHIA has been very prevalent of late and is causing many demands for a renewal of the construction work of the uncompleted filter plants, which work has been almost entirely suspended for the eight months that have elapsed since the investigations of the alleged frauds in connection with the contracts. It is stated that on Feb. 14 there were 1,977 cases of typhoid fever in Philadelphia and that there had been 121 deaths from the disease since Jan. 1. Since the beginning of December, it is stated that more than 3,000 cases of typhoid have been reported. Mayor Weaver has sent a letter to Messrs. W. B. Parsons, John D. Maclennan and Major Cassius E. Gillette, the committee of expert engineers on the filtration work, asking them, after completing their report on the Torresdale conduit, to decide as soon as possible upon the advisability of continuing work along such lines as are in the nature of serious departures from the plans laid down by the special commission of some years ago, which outlined a filtration system for Philadelphia. These departures include the omission of a filter plant at Queen Lane reservoir and instead an increase in the Torresdale plant, the abandonment of the Queen Lane pumping main, and reservoir, and the construction of preliminary filters. The mayor asks the opinion of the committee as to the advisability of putting in a temporary pumping station at Torresdale with a view of its abandonment for an intake higher up on the Delaware River, in the hopes of avoiding some of the pollution. He also inquires as to the advisability of completing the present plans for preliminary filters at Belmont and at Torresdale, and as to what use should be made of the Oak Lane reservoir, which was not a part of the plan of the original commission. Plans are now ready, he states, for the Torresdale pumping plant, and in the natural course of events bids would be called for at once. Inasmuch as the city is paying interest charges of $1,200 daily on the expenditure already made for the Torresdale plant, and in view of the prevalence of typhoid fever throughout the city, the mayor requests the experts to report on the questions outlined above by Feb. 25, if possible. The mayor also states that he should like to see the whole filtration system completed within twelve or fifteen months, and asks for the opinion of the experts "as to the best way of so dividing up the contracts that we can have a number of contractors doing work on them at one time and have the greatest amount of competition." A day or two after the sending of the letter outlined above, both branches of the Philadelphia Councils passed resolutions citing the prevalence of typhoid in Philadelphia, and asking the mayor for the earliest practicable information regarding the exact conditions of the filtration work, the probable cost of completing the same, when bids will be asked for necessary additional work, and the probable length of time required to complete the system.

TYPHOID FEVER DEATHS IN NEW YORK STATE numbered 1,554 during 1905, according to the report of Dr. Eugene H. Porter, State Commissioner of Health. Dr. Porter says that it is no exaggeration to attribute almost every one of these deaths to infected water. While there may be some doubts as to this statement, unquestionably many of the deaths were so caused, and there is no doubt but what his recommendations for a better sanitary control of the potable water of the state should be heeded. He recommends legislation "providing that all plans for public water supplies be approved by the State Commissioner of Health, and also to secure inspection of proposed and existing sewer systems and water supplies." Deaths from all causes for the whole state in 1905 aggregated 137,816, which, using the 1905 State Census population of 8,067,308, gives a death rate of 17 per 1,000. The birth rate for the state for the year was 21.3 per 1,000 population.

THE PREVENTION OF WATER POLLUTION IN Virginia is proposed by a bill introduced in the Legislature of that state. The bill makes it a misdemeanor to dump filth of any kind into streams, ponds and reservoirs used for public water supplies, and also provides for the treatment of sewage from factories before it can be discharged into streams.

FLOOD STORAGE RESERVOIRS on the headwaters of the Hudson and Mohawk rivers are favored by the New York State River Improvement Commission established in 1905. It is stated that the commission has recommended its own abolition and the entrusting of the work of constructing reservoirs to a new commission. The present commission is made up of several state officials, including Mr. H. A. Van Alstyne, State Engineer and Surveyor, and in addition there is an engineer-member in the person of Mr. Wallace C. Johnson. Mr. Johnson has reported to the commission on the subject of reservoir construction. He says that flood reservoirs in the Mohawk drainage area might be provided in the vicinity of Trenton Falls, Little Falls, points between Little Falls and Ft. Hunter along the lower course of the Schoharie, and on West Canada, East Canada, Oriskany and Nine-Mile creeks. On the upper Hudson, 19,000,000,000 cu. ft. of storage might be provided on the Sacanadaga, 16,000,000,000 on the Schroon at Tumble Falls, and a total of 5,000,000,000 cu. ft. in several reservoirs on the Battenkill. The Indian Lake reservoir has a capacity of about 5,000,000,000 cu. ft. These and other possible reservoirs would provide a total storage capacity above Albany of 54,000,000,000 cu. ft., thus giving relief from floods at Albany, Troy and Rensselaer, and also making it possible to increase the low-water level of the Hudson at Albany by 2½ ft.

A NEW LAW FOR COMMON CARRIERS has been established by the United States Supreme Court in the decision in a suit for an injunction brought by the Interstate Commerce Commission against the Chesapeake & Ohio R. R. The latter had contracted to deliver to the New York, New Haven & Hartford R. R. a large quantity of New River coal at $2.75 per ton. The price of coal at the mines, plus the cost of transportation at the published rates, amounted to nearly $4.00 per ton, and the Commission contended that this constituted a discrimination in rates. The railway denied this, and claimed that the New Haven had lost a large amount of money because of default of the Chesapeake & Ohio in carrying out an earlier contract for the delivery of coal, for which reason the Chesapeake & Ohio entered into the present contract as a means of reimbursing the New Haven for its loss. The Court decides against the railway and holds that the contract is illegal and void, on the ground that it plainly constitutes a means for accomplishing a discrimination which it is the evident intent of the Interstate Commerce Act to prevent. The Court, in the course of its lengthy opinion, says:

> It cannot be challenged that the great purpose of the act to regulate commerce while seeking to prevent unjust and unreasonable rates, was to secure equality of rates to all and to destroy favoritism, these last being accomplished by requiring the publication of tariffs and by prohibiting secret departures from such tariffs and forbidding rebates, preferences and all other forms of undue discrimination. . . . The all-embracing provision against either directly or indirectly charging less than the published rates shows that the purpose of the statute was to make the prohibition applicable to every method of dealing by a carrier by which the forbidden result could be brought about. . . . Now, if by the mere fact of purchasing and selling merchandise to be transported, a carrier is endowed with the power of disregarding the published rates, it becomes apparent that the carrier possesses the right to treat the owners of like commodities by entirely different rules. That is to say, the existence of such a power in its essence would enable a carrier, if it chose to do so, to select the favored persons from whom he would buy and the favored persons to whom he would sell, thus giving such persons an advantage over every other, and leading to a monopolization in the hands of such persons of all the productions as to which the carrier chose to deal.

This thought is greatly amplified and developed in the opinion, and is applied to the various arguments raised by the defendant, with the result of overthrowing them. The opinion concludes with the following decision:

> We therefore conclude that the injunction below should be embodied and enlarged by perpetually enjoining the Chesapeake & Ohio from taking less than the rates fixed in its published tariff of freight rates, by means of dealing in the purchase and sale of coal. And as thus modified the decree below is affirmed.

THE PENNSYLVANIA WATER SUPPLY COMMISsion, created about the middle of 1905, has been engaged since that time in collecting information regarding the water resources of the State. It proposes to consider this subject by the main drainage basins of the Delaware, Susquehanna, Ohio and Potomac regions, and a fifth basin, which it names the Lake Erie and Northern. Heretofore, the report states, no consideration has been given to water supplies as a part of the natural resources of the State. The contamination of streams, so far as it affects domestic and municipal supplies, is under the control of the State Health Department, but it is probable that the State Water Supply Commission will find it advisable to investigate obstructions to waterways, and also sources of pollution which affect the industries of the State. Flood and drouth conditions will also be studied. Under the provisions of the act creating the commission, the approval of the latter is necessary for all charters issued to water supply companies. Up to the close of 1905 the commission had received 18 applications for charters, of which it had granted seven and refused two; two applications had been withdrawn, and seven were under consideration. Mr. John Birkinbine, of Philadelphia, is engineer-member of the commission.

THE WATER POWER PLANT on the Chicago Drainage Canal at Lockport, Ill., will furnish electric current to the municipalities within the Chicago Sanitary District at a price which is practically the cost of production, as stated in the following letter recently sent out by Mr. R. R. McCormick, President of the Drainage Board. The power will be available by January, 1907:

> The Trustees are prepared to enter into contracts with any and all municipalities within the limits of the District for such electrical energy as may be required for municipal purposes at a cost price of $26.40 per HP. per year on a basis of 24-hour service. It is probable that some of the municipalities cannot make use of power 24 hours a day, and in such event a service of 12 hours will be furnished at a price of $20, and the Trustees will endeavor to dispose of the power for the remaining 12 hours. The price of $26.40 represents the true cost to the sanitary district, with 15,500 HP. delivered at the substation.
>
> Power will be delivered to purchasers at the substation at West 48th Ave. and the canal. The responsibility and cost of transmission from that point must be assumed by the purchasers.
>
> When the full flow of water is available in the canal, which will probably be within six or seven years, the power can be increased to 31,000 HP. with an additional outlay of $450,000. The true cost will then be reduced to $14.97, and it is the intention of making a provisional reduction to this figure in all contracts.

THE ILLINOIS DEEP WATERWAY project for establishing a 14-ft. navigable channel from Lake Michigan to the Mississippi River is to be studied by the Internal Improvement Commission of Illinois which was authorized by the last meeting of the state legislature. The Governor has appointed the members of this commission, as follows: Isham Randolph, M. Am. Soc. C. E., of Chicago; Henry M. Schmoldt, of Beardstown, Ill., and Henry W. Johnston, of Ottawa, Ill. The government report on the waterway project in connection with the Chicago Drainage Canal was recently referred to in our columns, but it is stated that no action upon this will be taken until next year. There is, however, another bill before Congress which provides for the waterway construction and development of water power by private interests, independent of the Chicago Drainage Canal. This latter project would interfere with the Drainage Board's plans for the development of 11,000 HP. at Hickory Creek, by acquiring the water rights and paying very small compensation. The bill provides that the construction work shall be done by the three allied companies backing it (Joliet Power Co., Ottawa Power Co. and North St. Louis Power Co.), but shall be paid for by the government by an issue of bonds for $60,000,000.

A BREAK IN THREE LARGE WATER MAINS in Convent Ave., at about 128th St., New York City, was caused on Saturday, Feb. 17, by rock thrown into the street from a large blast. There were at this point eight 48-in. mains, three of which were broken. A large piece, said to be the diameter of the mains and 6 ft. long, was broken out of each of two of the mains, and a third

main was cracked. A considerable area in the vicinity was flooded and some of the plant at the power station of the New York City railway was badly damaged. The contractor's foreman was arrested and fined $25. The work on which the blast was made was being done by private contract.

THE STREET RAILWAYS and other municipal industries owned and operated by the Public Service Corporation of New Jersey have been taken over by the United Gas Improvement Co., of Philadelphia. The transfer involves the street railways and a large part of the lighting service of Jersey City, Newark and many communities of lesser size in the vicinity.

MUNICIPAL STREET RAILWAYS AT BELFAST, Ireland, were put in full operation on Dec. 5, 1905, according to a report from U. S. Consul Knabenshue, of Belfast. The city was the last one of any magnitude in the United Kingdom, the Consul states, to change from horse to electric traction and from private to public ownership. The franchise did not expire until 1907, but through negotiations between the company and the city, and by the aid of a parliamentary act in 1904, the property of the company was acquired by the city. The act provided that the value of the property should be determined by arbitration, and that in addition to the sum so determined the city should pay three years' profit to the company and three years' compensation to its officers. The city issued £1,000,000 ($4,870,000) of bonds and began the work of reconstruction in February, 1905. There are 36 street miles of double track, or with turnouts a track mileage of 73 miles.

BAD AIR IN THE STREET CARS OF DETROIT is reported by Health Officer Keifer. Analyses have shown that at times when the carbon dioxide in the open air was 3½ parts per 10,000, the air in the street cars (Jan., 1905) showed from 16 to 51.2 parts per 10,000. The tests were made to compare the efficiency of various systems of ventilation. In most cases, the carbon dioxide did not run much above 15 parts per 10,000.

PUBLIC SERVICE CORPORATIONS IN TEXAS owning, leasing or operating street railway, electric lighting or power plants, gas, water or sewage plants, in any place of 2,500 population and over, must, on or before March 1, 1906, report to the Secretary of State on their business operations for the year, and similar reports will be required annually hereafter. The information is desired for use in making assessments for taxation. In compliance with the law, Secretary of State Shannon has prepared blank forms requiring information on the following points: Common and preferred stock issued, and amount due on unpaid stock; bonds sold, price realized, date of maturity and rate of interest; other fixed liens or mortgage on property; floating indebtedness, including all bills payable; value of all tangible property, including lands, machinery, buildings, tracks, equipment, bills receivable and cash on hand; annual operating expense, including salaries, wages, taxes, interest, insurance, fuel, repairs, extensions, maintenance, claims and damages, and miscellaneous expenses; gross earnings; prices charged private consumers per thousand units of water, gas, power, electric light and sewerage, and rates of fare per street railway passenger; prices charged municipalities for hydrant rental and for street lights.

ELECTRIC SUBURBAN OPERATION is being studied by the Erie Ry. A consulting commission has recently been formed by Vice-President J. M. Graham to study the application of electric traction to the extensive suburban network of the Erie. Mr. Graham heads the commission as chairman; other members are E. A. Williams (Gen. Mechanical Superintendent), A. J. Stone (Asst. Gen. Manager), C. H. Morrison, B. J. Arnold, and L. B. Stillwell.

PERSONALS.

Mr. Charles M. Hayes, Vice-President and General Manager of the Grand Trunk Ry., has gone to England on a brief business trip.

Mr. Howard K. McLean, for a number of years General Superintendent of the Link-Belt Machinery Co., is now associated with the H. W. Caldwell & Son Co., of Chicago, as Consulting Engineer.

Mr. A. B. Newell, formerly Vice-President and General Manager of the White Pass & Yukon Route, has resigned and taken a position with McCord & Co., manufacturers of railroad supplies, 24 Broad St., New York City.

Mr. J. D. Mathews, Resident Engineer, having resigned to take service with the Cananea, Yaqui River & Pacific Railroad Co., Mr. W. S. Pratt has been appointed Acting Resident Engineer, at Guaymas, Sonora, Mexico.

Mr. H. W. Henderson, formerly Superintendent of the Salt Lake division of the San Pedro, Los Angeles & Salt Lake R. R., has been appointed General Manager of the Guayaquil & Quito Railroad in Ecuador, South America.

Mr. J. K. Geddes, General Manager, of the Ohio River & Western Ry., has been appointed Chief Engineer in charge of construction. Mr. J. F. Scott has been appointed Master Mechanic at Zanesville, O., succeeding Mr. V. B. Stubbins.

Mr. Leonard M. Cox, M. Am. Soc. C. E., who recently resigned his commission as Civil Engineer in the United States Navy, has accepted the position of Chief Engineer of the Louisville, Henderson & St. Louis Ry. Co., with headquarters at Louisville, Ky.

Mr. H. C. Nutt has resigned as General Superintendent of the Missouri district of the Chicago, Burlington & Quincy Ry., to accept the position of General Superintendent of the Michigan Central R. R., with headquarters at Detroit, Mich., succeeding Mr. H. A. Worcester, resigned.

Mr. J. C. Stevens, hydrographer at Washington, D. C., has been ordered to report immediately to D. C. Henry, Supervising Engr., Portland, Ore., to take charge of the hydrographic work of the United States Geological Survey in the states of Oregon and Washington, with headquarters at Portland, Ore.

Mr. W. A. Gibbs, General Manager of the Zanesville Railway, Light & Power Co., of Zanesville, O., has been appointed General Manager of the Columbus, Newark & Zanesville and the Columbus, Buckeye, Lake & Newark railway companies, succeeding Mr. J. R. Harrigan, who has become General Manager of the Canton-Akron system.

Taotai Jeme Tien-you, a graduate of Yale University, Sheffield Scientific Department, A. M. I. C. E., London, and Superintending Engineer of the Peking-Changchaikou (Kalgan) Railway, now in course of construction, has been appointed by the Chinese Board of Commerce, at Peking, as special advisor on railway matters to that board.

Mr. H. C. Humphrey, M. Am. Soc. C. E., formerly Provincial Supervisor of Tayabas Province, Philippine Islands, has been appointed District Engineer of the Seventh Engineering District of the Philippine Islands. The Seventh Engineering District includes the Provinces of Tayabas and Batangas, with headquarters at Lucena, Tayabas Province.

Mr. W. W. Cunningham, formerly Treasurer of the Pennsylvania Clay Co., manufacturers of vitrified fire clay paving brick, with factories at Conway, Fallston and Monaca, Pa., has been elected President and General Manager of the company. The Pennsylvania Clay Co.'s general offices have recently been removed from Rochester, Pa., to the Germania Savings Bank Building, Pittsburg, Pa.

Mr. C. A. Wentworth, Civil Engineer, in the United States Navy, has resigned his commission to take effect on March 1. Mr. Wentworth is from Massachusetts, and was appointed a civil engineer in the navy in June, 1902. Since March, 1904, he has been stationed at the naval station at Guantanamo, Cuba. He will be succeeded on that station by Civil Engineer F. R. Harris, now on duty at the Charleston, S. C., naval station.

Mr. George T. Ross., General Superintendent of the Iowa district of the Chicago, Burlington & Quincy Ry., has been appointed General Superintendent of the Missouri district, with headquarters at St. Louis, Mo., to succeed Mr. H. C. Nutt, resigned. Mr. W. B. Throop, Superintendent of the Aurora division at Aurora, Ill., has been appointed General Superintendent of the Iowa district, with headquarters at Burlington, Ia., in place of Mr. Ross.

Obituary.

Carl F. Rehman, an architect, of Newark, N. J., died on Feb. 17, at his home, 498 Mount Prospect Ave., of blood poisoning. He was born in Germany and was 53 years old. He leaves a widow and two daughters.

Henry A. V. Reaney, Chief Clerk of the United States Lighthouse Inspectors' office, died at Detroit, Mich., on Feb. 19, of paralysis. He was a native of Dublin, Ireland, and served in the United States Navy during the civil war, becoming a captain.

James Hastings, an inspector in the plumbing division of the Borough of Manhattan Building Bureau, New York City, died recently at his home, 605 Hudson St., of a complication of ailments. He was born in the old Greenwich Village section of New York, 36 years ago, and was made an inspector in the old Department of Buildings by Commissioner Thomas J. Brady, in 1898.

David B. Bogert, said to have been the oldest locomotive engineer in the United States, died at his home in Passaic, N. J., on Feb. 19, from a complication of diseases. He was 86 years old, and for 46 years uninterruptedly was employed as engineer by the Erie Railroad. Mr. Bogert was in charge of the first engine to go over the Erie's entire system with hard coal as fuel. He was born at Tappan, N. Y.

John W. Thomas, President of the Nashville, Chattanooga & St. Louis Ry., died at his home in Nashville, Tenn., on Feb. 12, at the age of 75 years. He was born in Nashville, Tenn., on August 24, 1830, and entered railway service in November, 1858, as agent of the Nashville & Chattanooga Railroad, at Murfreesboro, Tenn. Mr. Thomas continued in the service of this company, the title of which was later changed to its present one, until his death. He was in charge of rolling stock from January, 1863, to July, 1865, Auditor and Treasurer from the latter date to September, 1868, and Superintendent from September, 1868, to September, 1880. He was then for eleven years General Superintendent. In September, 1883, was appointed General Manager. In September, 1884, he was appointed President and General Manager and held both offices until January 1, 1890, when he relinquished the duties of general manager and was succeeded in that position by his son, Mr. John W. Thomas, Jr.

Charles Napier Bell, M. Inst. C. E., an eminent English civil engineer, died at Derby, Tasmania, Australia, on Jan. 3, after a long illness. He was born in Rothesay, Scotland, in 1835, and studied his profession as a pupil of Bell & Miller, of Edinburg. His early professional work was in South America, where he built 40 miles of the San Paulo Railway in Brazil, and was connected with surveys for the Pernambuco Ry., the Buenos Aires harbor works and other enterprises. In 1869 he was in Europe engaged on the Baxter en Wesel Ry., in Holland, and later on gas and water supply plants for Bereditcheff in South Russia. In 1871 Mr. Bell went to New Zealand and was engaged on important railway and water supply works for several years. In the early 80's he was engaged by the Tasmanian Government to supervise its most important harbor and railway works, and thereafter was connected in a consulting capacity with many of the important engineering works of Australia. He became a Member of the Institution of Civil Engineers in 1869 and was elected to its Council two years ago.

ENGINEERING SOCIETIES.

COMING MEETINGS.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.
March 20-22. Annual meeting at Chicago, Ill. Secy., L. C. Fritch, 1562 Monadnock Block, Chicago, Ill.

AMERICAN RAILWAY ASSOCIATION.
April 25. Semi-annual meeting at Chicago, Ill. Secy., W. F. Allen, 24 Park Place, New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
May 1 to 4. Semi-annual meeting at Chattanooga, Tenn. Secy., F. R. Hutton, 12 West 31st St., New York City.

FARADAY SOCIETY (Great Britain).—The following have been nominated for officers of the society for the coming year: President, Lord Kelvin; vice-Presidents, Prof. A. Crum-Brown, Prof. W. Hittorf, Sir William Huggins, Sir Oliver Lodge, Mr. Ludwig Mond, Lord Rayleigh, Prof. J. J. Thomson; Treasurer, Mr. F. M. Perkin.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—The February "reunion" of the society will take place at the society house, 12 West 31st St., New York, on the evening of Tuesday, Feb. 27. Mr. J. M. Dodge, of the Link-Belt Engineering Co., will present a paper entitled "Some Practical Results from the Introduction of a Modern System of Shop Management."

SOCIETY OF CHEMICAL INDUSTRY.—An interesting subject will be discussed at the next meeting of the New York Section, to be held at the Chemists' Club, 108 West 55th St., New York, on the evening of Feb. 23. The general subject is Smoke Prevention, and some half a dozen papers on different phases of this subject are expected, as follows: "Municipal Regulation of the Smoke Nuisance," by Thomas Darlington; "The Use of Soft Coal Under Boilers," by A. de Tampe; "Down-Draft Without Grates," by L. H. White; "Smoke and Smoke Prevention as Affected by Furnace Construction," by W. R. Roney; "Filtration of Smoke," by W. Bowman; "A Practical Way of Building Smokeless Furnaces," by E. H. Foster; "Smoke Prevention by Means of Down-Draft Fire and Gas Firing," by O. Nagel.

MONTANA SOCIETY OF ENGINEERS.—At the society's annual meeting, held at Lewistown, Mont., on Jan. 11 to 13, the proposition that the society withdraw from the Association of Engineering Societies was brought up. After some discussion it was decided to canvass the views of the membership of the society before taking further steps. The meeting elected the following officers for the coming year: President, B. H. Dunsheer; vice-Presidents, E. C. Kinney and A. E. Wheeler; Secretary, Clinton H. Moore; Treasurer and member of board of managers of the Association of Engineering Societies, Samuel Barker, Jr.; Trustee, George W. Wilson. The meeting was largely occupied by trips of inspection to the gold mining camps of Fergus County, the Kendall, the Barnes-King, and the Gold Reef. The proceedings of the technical session of the meeting comprised the address of the retiring president, Mr. E. W. King, and papers by Prof. C. H. Bowman, G. W. Craven, A. M. Plumb, O. F. Wasmansdorff, F. F. Goss, and C. M. Thorpe.

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